State of California
The Resources Agency
Department of Water Resources
Environmental Services Office

SUISUN MARSH MONITORING PROGRAM

REFERENCE GUIDE

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Version 2

Contents

Chapter 1
Introduction

The purpose of this document is to provide background information to supplement the Suisun Marsh Monitoring Program Data Summary reports. Before water year 1997, this information was included in each annual report. In an effort to streamline the report preparation process and focus on the data required by regulatory permits, this background information was removed from the water year 1997 Data Summary Report and will not be included in subsequent reports. Copies of the Suisun Marsh Monitoring Program Data Summary reports are available for water years 1988 through 1997 by contacting Mike Floyd, California Department of Water Resources, Environmental Services Office, (916) 227-7520; E-mail, mfloyd@water.ca.gov. This and other California Department of Water Resources (DWR) Suisun Marsh Program reports are also available on the Internet at **http://iep.water.ca.gov/suisun**.

The Suisun Marsh is located in southern Solano County, California, approximately 35 miles northeast of San Francisco. The Suisun Marsh is bordered on the east by the Sacramento-San Joaquin Delta (Delta), on the south by Suisun Bay, on the west by state Highway 680, and on the north by Highway 12 and the cities of Suisun and Fairfield (Figure 1). Suisun Marsh is one of the largest contiguous brackish water marshes remaining in the United States and is an important part of the San Francisco Bay-Delta Estuary (DWR 1984). This tidally influenced marsh provides important habitat for more than 221 avian species, 45 mammalian species, 16 reptilian and amphibian species, and over 40 fish species (DFG 1989; Meng and Moyle 1993). The Suisun Marsh is a mosaic of seasonally managed wetlands, unmanaged tidal wetlands, bays, and sloughs bordered by upland grasslands.

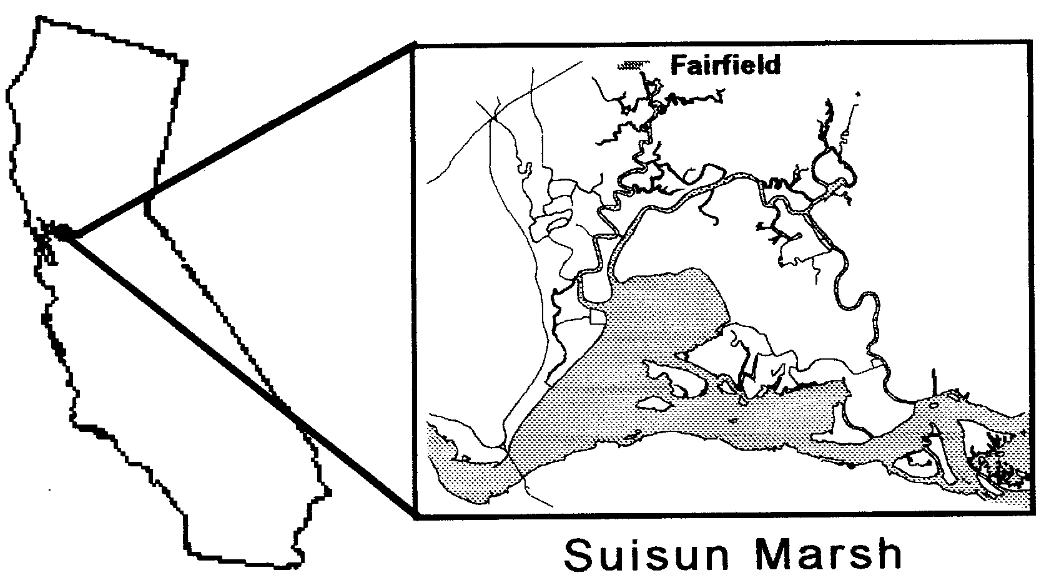


Figure 1 Location of Suisun Marsh

Like so much of California, the history of Suisun Marsh has been shaped by water. This brackish marsh was originally formed by erosion, sedimentation, and the dynamics of a tidal system where fresh river water and saline ocean water meet. More recently, the politics of water have occupied private citizens and governmental agencies in an effort to protect the Suisun Marsh and its wetlands, water quality, wildlife habitats, and recreational values.

In 1987, DWR, the California Department of Fish and Game (DFG), US Bureau of Reclamation (USBR), and Suisun Resource Conservation District (SRCD) signed the Suisun Marsh Preservation Agreement (SMPA), which included the following provisions:

- The construction of facilities to deliver lower salinity water to portions of the Suisun Marsh and meet water quality standards.
- A monitoring program to collect data on surface and soil water quality, water elevations, vegetation, and wildlife species.
- Wetlands mitigation for effects of facilities construction and upstream water diversions.
- Wetland improvements through use of management plans and a cost-share program for installation and improvement of water conveyance facilities.

Suisun Marsh monitoring requirements are described in detail in the Suisun Marsh Monitoring Agreement, also signed by all the SMPA signatories, except SRCD, in 1987.

Chapter 2
Description of Suisun Marsh

Marsh Environment

The Suisun Marsh is located in southern Solano County, California, west of the Sacramento-San Joaquin Delta and north of Suisun Bay (see Figure 1). This intricate land-water area of tidal wetlands, diked seasonal ponds, sloughs, and upland grasslands comprises over 10% of the remaining wetlands in California, and is an important part of the San Francisco Bay-Delta Estuary. The Suisun Marsh provides habitats for many species of plants, fish, and wildlife, in addition to wintering and nesting habitat for waterfowl on the Pacific Flyway. Suisun Marsh is a brackish marsh due to the combined influences of saline ocean water from Suisun Bay and fresh water from the Sacramento-San Joaquin Delta.

The Suisun Marsh was originally formed by the deposition of silt particles from flood waters of Suisun Slough, Montezuma Slough, and the Sacramento-San Joaquin river network. In it's original state, the Suisun Marsh consisted of islands separated by a network of tidal sloughs. Large portions of these islands were submerged daily by the high tides, while larger tracts of land were submerged during seasonal high tides and winter flood events. The salinity of the water in the sloughs of the Suisun Marsh varied considerably with season and from year to year. High winter and spring outflows from the Delta and local streams flooded the Suisun Marsh and provided fresh water in its channels. During periods of low outflow, however, saline water from the bay gradually replaced the fresh water in Suisun Marsh channels, resulting in high salinity for periods of up to five months or more each year (DPW 1931a).

The native vegetation of Suisun Marsh consisted of aquatic plants such as tules (*Scirpus* sp.), cattails (*Typha* sp.), and rushes (*Juncus* sp.) in the areas of continuous flooding; salt grass (*Distichlis spicata*) on the higher ground not usually flooded; and pickleweed (*Salicornia virginica*) in isolated areas of poor drainage. Salt grass was the predominant vegetation of most of the marsh. Before any reclamation occurred, these marshlands were used as beef and dairy cattle pastures (DPW 1931a).

Levee construction in Suisun Marsh began in the 1860s after the US Congress granted to the states all swamps, marshes, and sloughs; and subsequent State legislation transferred “swamp land” into private ownership to be drained for development. Following the initial construction of low sod levees, and filling of some smaller sloughs with material borrowed from higher ground, salt grass replaced the aquatic vegetation and the marshlands were more effectively utilized for cattle grazing. Agricultural crops such as beans, asparagus, wine grapes, hay, and grains were successfully raised on some areas of reclaimed land after leaching operations effectively removed salts from the soil (Arnold 1996). This leaching was done by allowing precipitation to accumulate on the land and then draining it off through flood gates, and by flooding the land with fresh water when it was available from Suisun Marsh channels (DPW 1931a). In some cases, reclamation of the land required five or six years of such leaching (DPW 1931b). Agricultural developments, in spite of reclamation improvements, were largely unsuccessful because of poor drainage and the accumulation of salts in the soils (George and others 1965). Diked areas that were unsuitable for agricultural production were left dry and used for cattle grazing, or were flooded on a seasonal basis and managed as private duck hunting clubs.

From about 1859 to 1879, market hunters were active in the Suisun Marsh, transporting great quantities of birds by boat to the San Francisco Bay Area. The first private duck clubs were organized around 1880

(Stoner 1937). Because of the large numbers of ducks in the marsh, and its proximity to San Francisco Bay Area hunters, by about 1930 waterfowl hunting became the primary use of the Suisun marshlands (Arnold 1996). Beginning in 1927, the State of California purchased portions of the Suisun Marsh as State wildlife management areas. In addition to waterfowl refuge areas and public hunting opportunities, these State areas were originally purchased to ease crop predation by waterfowl in the Central Valley (Mall 1969).

In addition to diking and draining, the Suisun Marsh has been modified over the years by natural erosion, upstream hydraulic mining, channel erosion, and changes in Delta outflow (Miller and others 1975).

Today the Suisun Marsh contains approximately 52,000 acres of diked wetlands, 6,300 acres of unmanaged tidal wetlands, 30,000 acres of bays and sloughs, and 27,000 acres of upland grasslands. Most of the diked wetlands are managed for waterfowl hunting; acreage devoted to grazing and agriculture is very small. DFG manages about 15,000 acres of tidal wetlands, diked wetlands, and upland grasslands.

Suisun Marsh Soils

Suisun Marsh soils are mixtures of hydrophytic plant remains and mineral sediments. As the Suisun Marsh formed, plant detritus slowly accumulated, compressing the saturated underlying base material. Mineral sediments were added to the organic material by tidal action and during floods. Generally, mineral deposition decreased with distance from the sloughs and channels (Miller and others 1975). Suisun Marsh soils are termed “hydric” because they formed under natural tidal marsh conditions of almost constant saturation.

All Suisun Marsh soils that were historically inundated by the brackish tides are saline soils. Salts are present throughout the soil profile and maintained there by the saline groundwater and by periodic flooding with brackish channel water. As with channel water, there is an increasing soil water salinity gradient in Suisun Marsh from east to west and from north to south.

The soils adjacent to the sloughs are mineral soils of the Reyes series. These soils have less than 15% organic matter, and although classed as “poorly drained,” they are better drained than the more organic soils in the marsh. Tamba soils occur adjacent to the Reyes soils, at a slightly lower elevation, and contain 15% to 30% organic material. Joice soils occur still farther from the sloughs and contain 30% to 50% organic matter. Suisun soils occur farthest from the sloughs, at the lowest elevations and have over 50% organic matter content. Another common soil in the Suisun Marsh is the Valdez series, which formed on alluvial fans and contain very low amounts of organic material. Valdez series soils are found primarily on Grizzly Island (Miller and others 1975). The Suisun Marsh is bordered by upland soils that are non-hydric and contain very little organic material.

Today, large areas of Suisun Marsh are contained within levee systems and water control structures and are managed as seasonal wetlands. By isolating the soils from daily tidal inundation, the soils have become more saline (DWP 1931b). All the soils are saline and poorly drained. When allowed to dry, these hydric soils tend to subside, thus lowering the elevation of the pond bottoms. Each marsh soil presents different challenges to the wetland manager. Reyes and Tamba soils become strongly acidic if exposed to air and allowed to dry. The Suisun and Joice soils are difficult to leach effectively because capillary action and hydrostatic pressure in these organic soils bring saline water upward through the soil profile, making it difficult to maintain low root zone salinity. In addition, Joice soils are prone to cracking.

Factors Determining Channel Water Salinity in Suisun Marsh

Below are some of the factors that determine the salinity in Suisun Marsh channels:

- Tides
- Climate (precipitation, evaporation, wind, and barometric pressure)
- Delta Outflow
- Suisun Marsh Salinity Control Gate operations
- Creek inflows
- Managed wetland operations
- Fairfield-Suisun Treatment Plant effluent inflows

In general, the first five factors have the greatest effects on channel water salinity. The last two factors have temporary or localized effects on channel water salinity. Monitoring in the Suisun Marsh has been focused primarily on the effects of Delta outflow, tides, Suisun Marsh Salinity Control Gate operations, and creek inflows.

During times of high Delta outflow, the Suisun Marsh has a natural salinity gradient from east to west. The eastern marsh, being closest to the Delta, will experience lower channel salinities than the western marsh. When Delta outflow is low, the operation of the Suisun Marsh Salinity Control Gates (SMSCG) (discussed further in the Physical Facilities section) lowers the salinity in eastern Suisun Marsh channels and maintains the east to west gradient. Without SMSCG operations during times of low Delta outflow, the salinity in the western Suisun Marsh may be lower than that at some eastern Suisun Marsh locations, particularly the area around Boldens Landing water quality monitoring station (station S-49) (Figure 2). The Suisun Marsh also has a north-south salinity gradient, with the northern Suisun Marsh having lower channel salinity during wet months due to local runoff and creek flows.

Salinity in the eastern Suisun Marsh drops rapidly when Delta outflow increases; however, the southwestern Suisun Marsh (as measured at S-35) requires high outflow for a longer period of time to achieve a reduction in salinity. Field data and simulation modeling indicate that northwestern Suisun Marsh salinity (monitored at S-97) is primarily affected by inflows from the watershed to the north and northwest, and by local drainage from managed wetlands.

Tides

Salinity monitoring throughout the Suisun Marsh indicates that in certain regions tides have a significant impact on channel water salinity, while in other regions this impact is less pronounced or non-existent. In general, salinity is higher at high tide and lower at low tide.

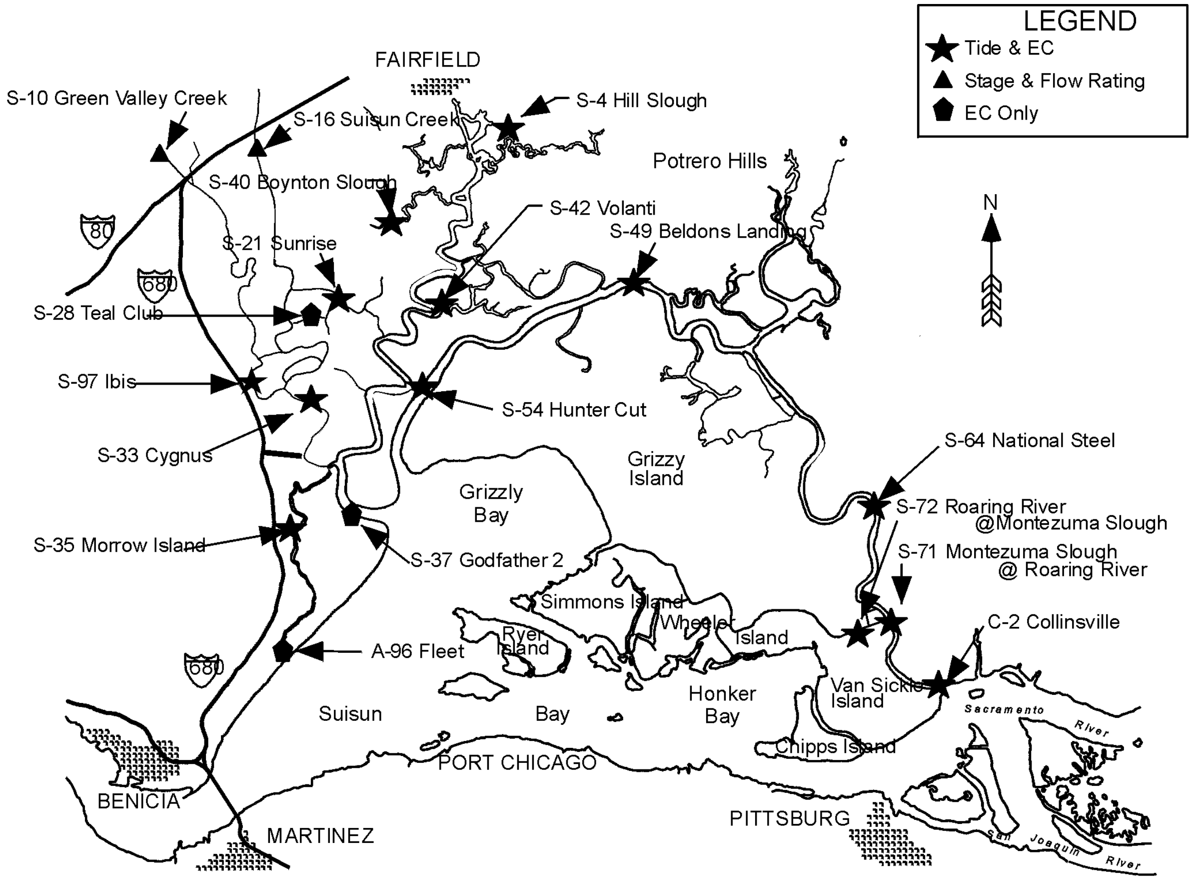
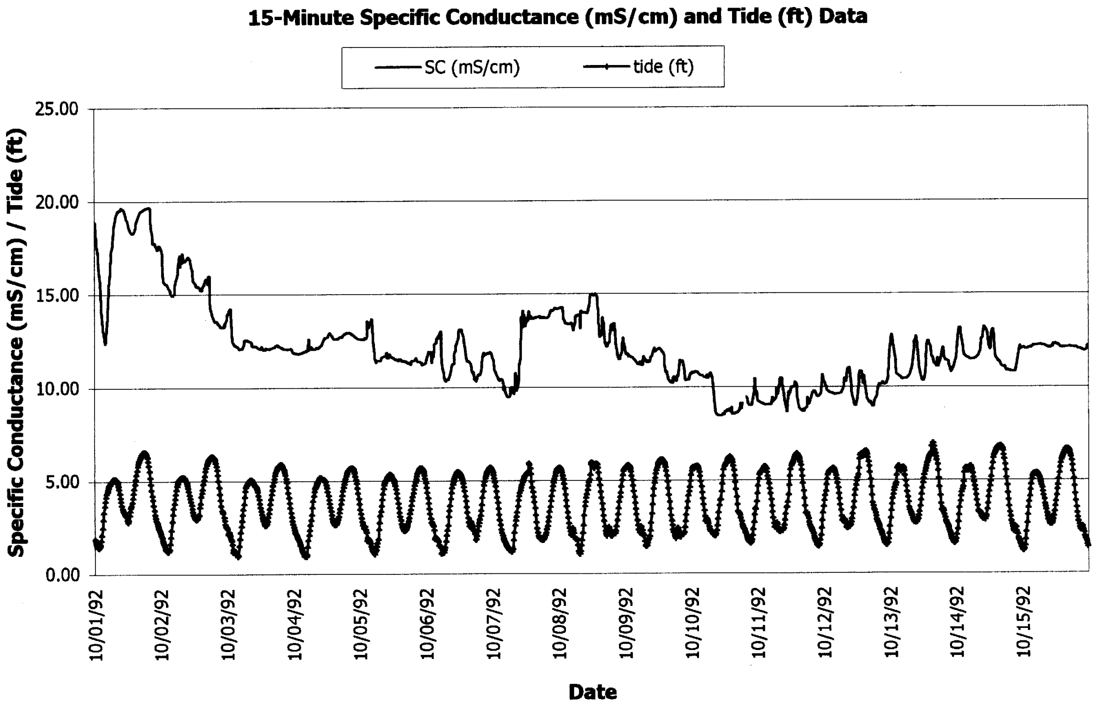


Figure 2 Suisun Marsh monitoring and compliance stations

To examine this more closely, 15-minute salinity and tide data were plotted for several eastern and western Suisun Marsh monitoring stations (top panels of Figures 3 through 10), along with mean daily high tide salinity and mean daily salinity (bottom panels of Figures 3 through 10). For comparison purposes, two sets of data were examined, namely, the first two weeks of October 1992 (see Figures 3 through 6) and October 1993 (see Figures 7 through 10). October of 1992 was preceded by a critical water year, while October 1993 was preceded by an above average water year. During both years, specific conductance at station S-21 had the largest variability, as much as 10 mS/cm between high and low tides. Stations S-42 and S-97 both showed low (within 2 mS/cm) or nonexistent variability in channel water salinity with change in tides.



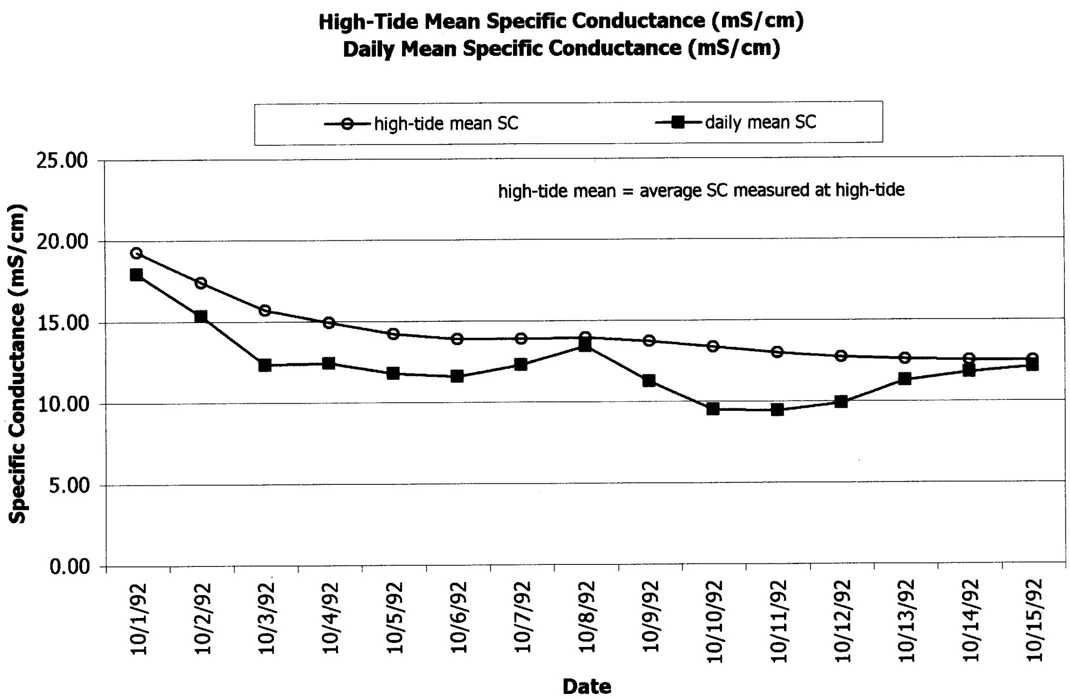
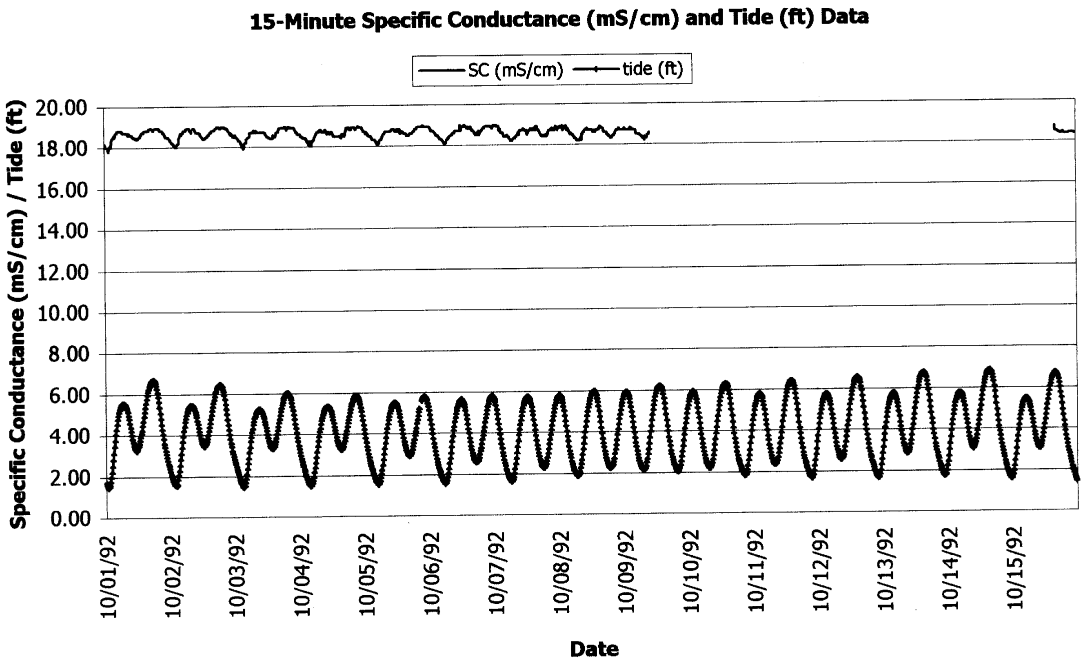


Figure 3 S-64 high versus mean tide salinity analysis from 1 to 15 October 1992



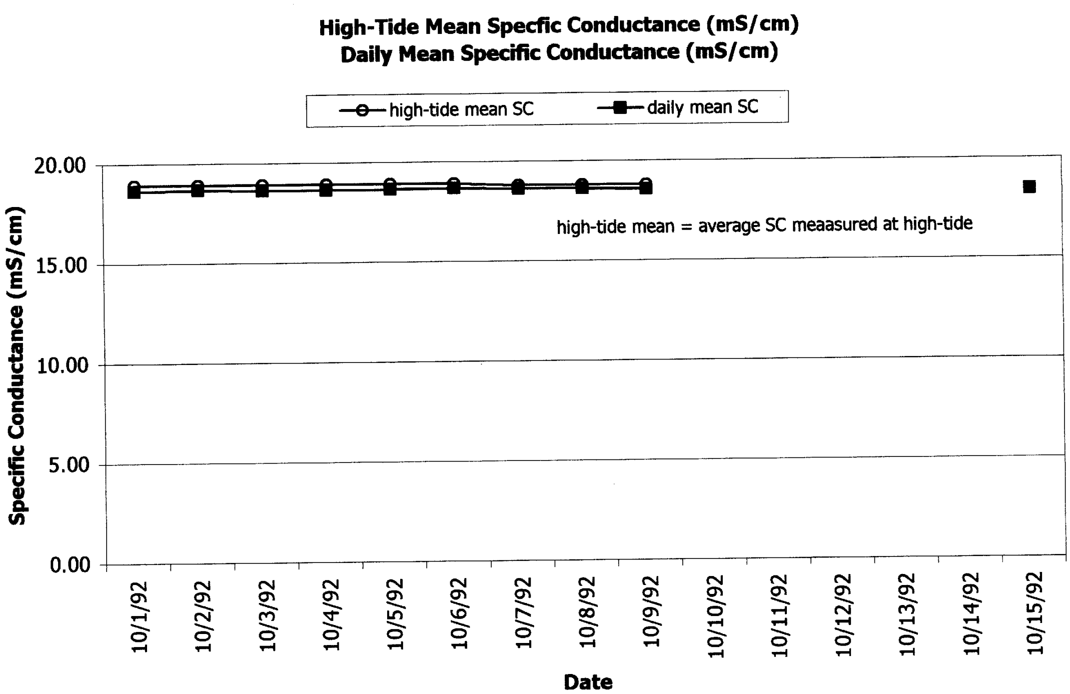
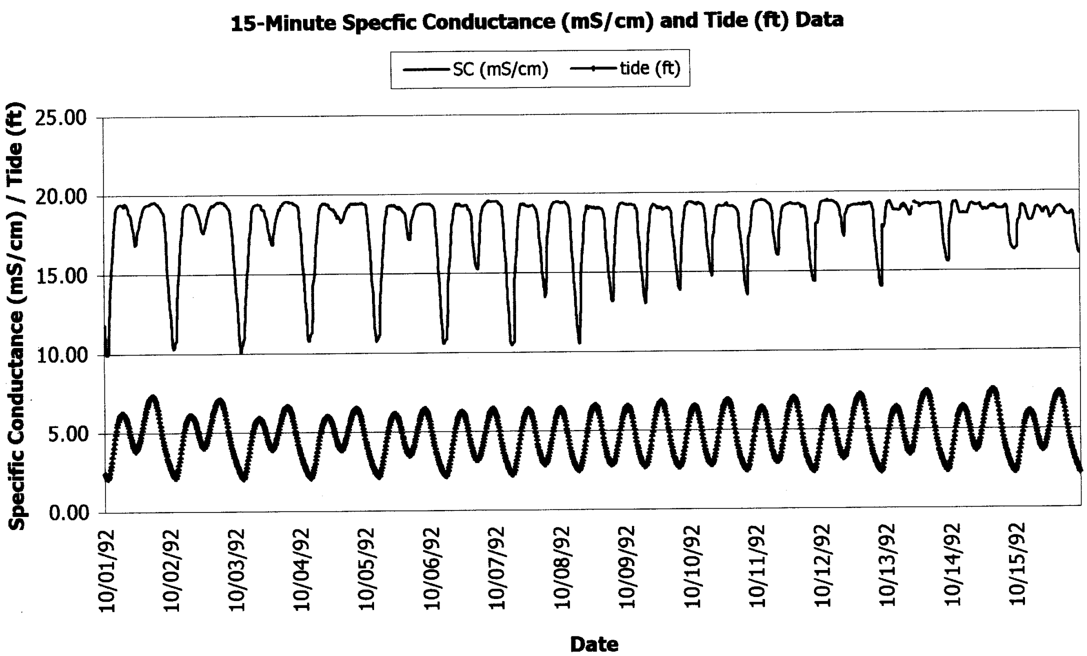


Figure 4 S-42 high versus mean tide salinity analysis from 1 to 15 October 1992



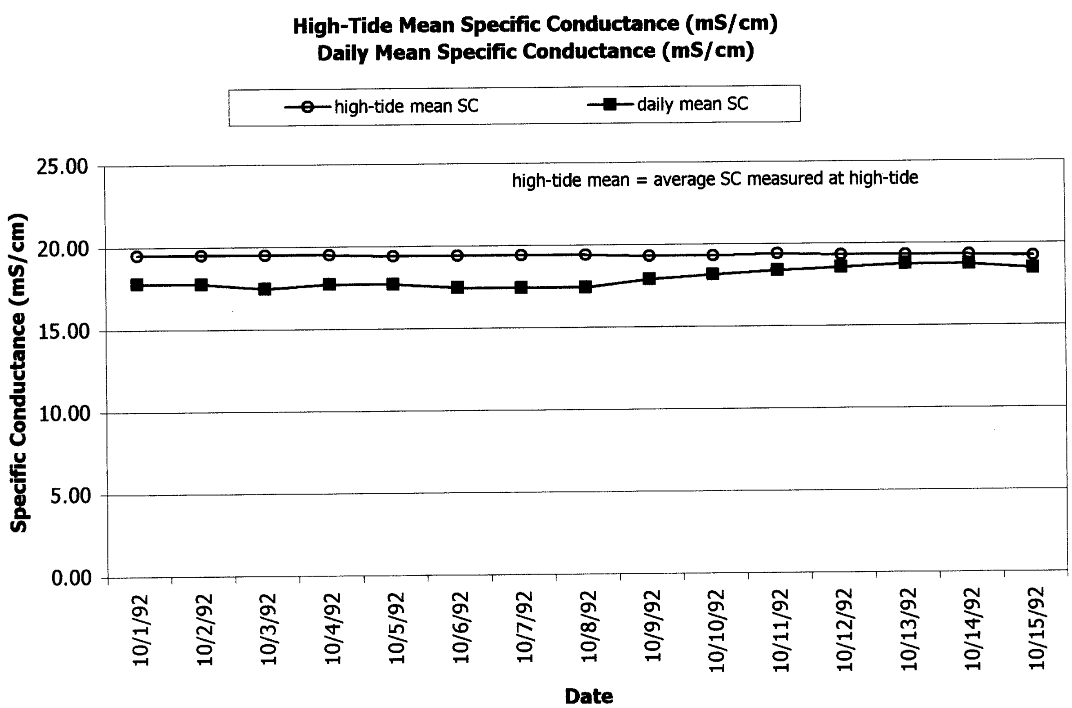
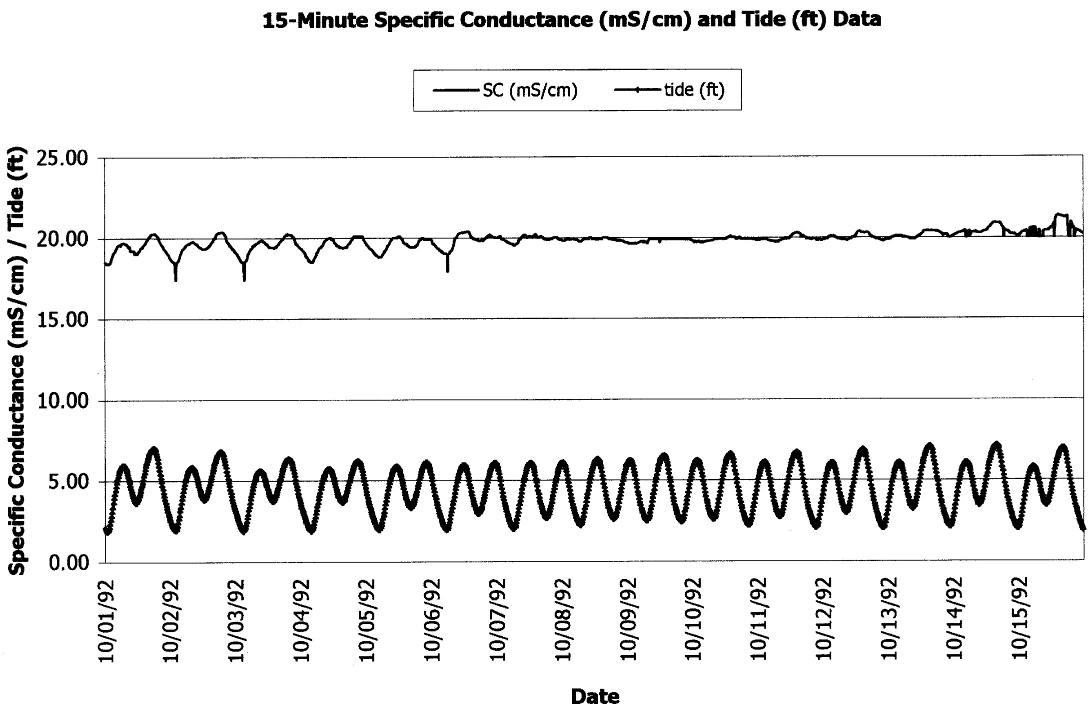


Figure 5 S-21 high versus mean tide salinity analysis from 1 to 15 October 1992



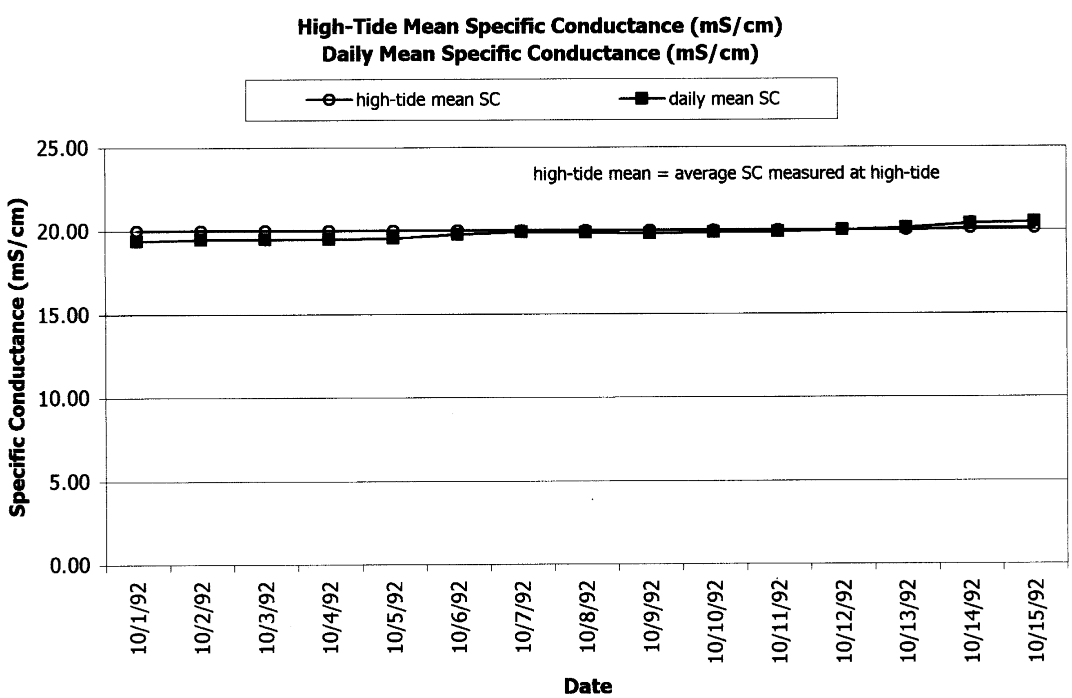
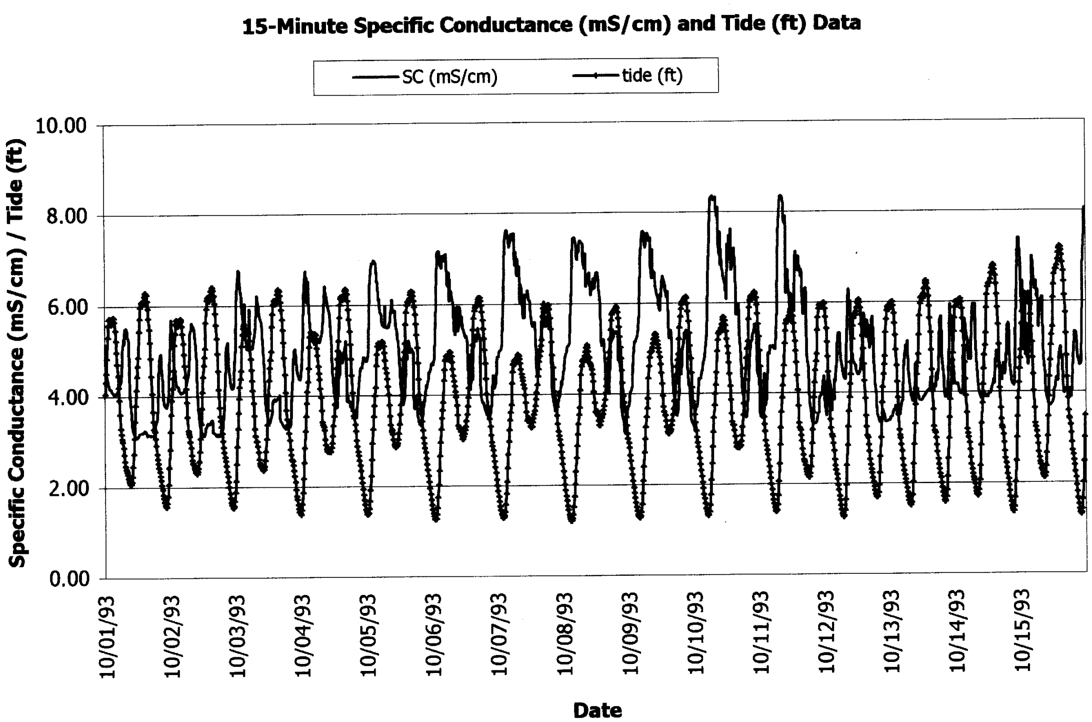


Figure 6 S-97 high versus mean tide salinity analysis from 1 to 15 October 1992



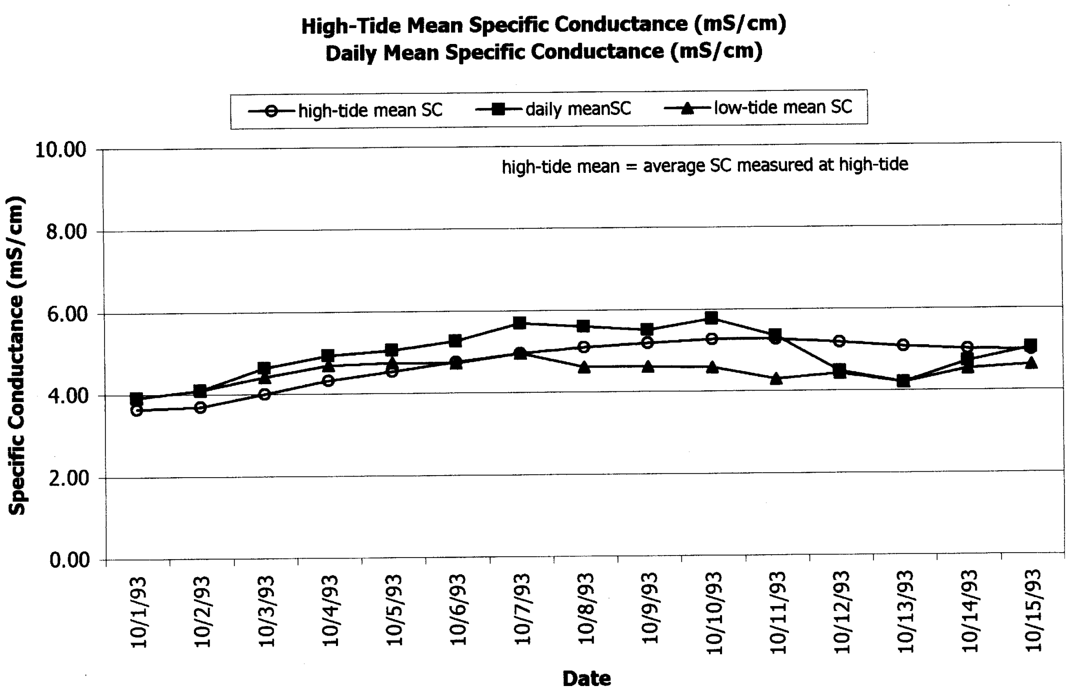
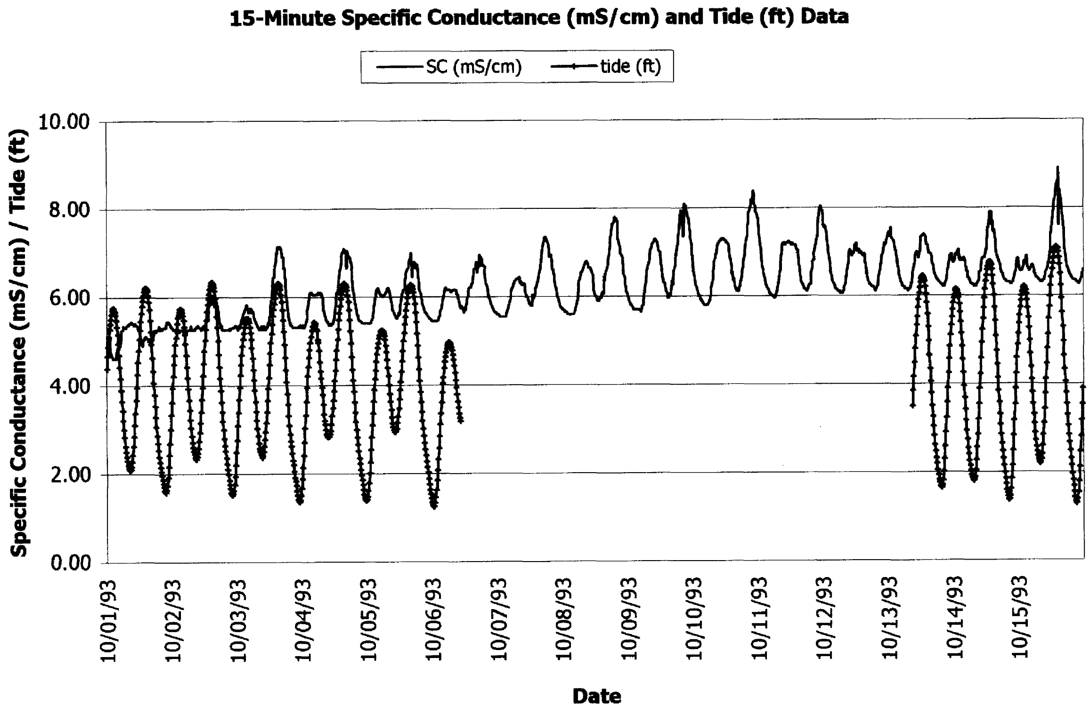


Figure 7 S-64 high versus mean tide salinity analysis from 1 to 15 October 1993



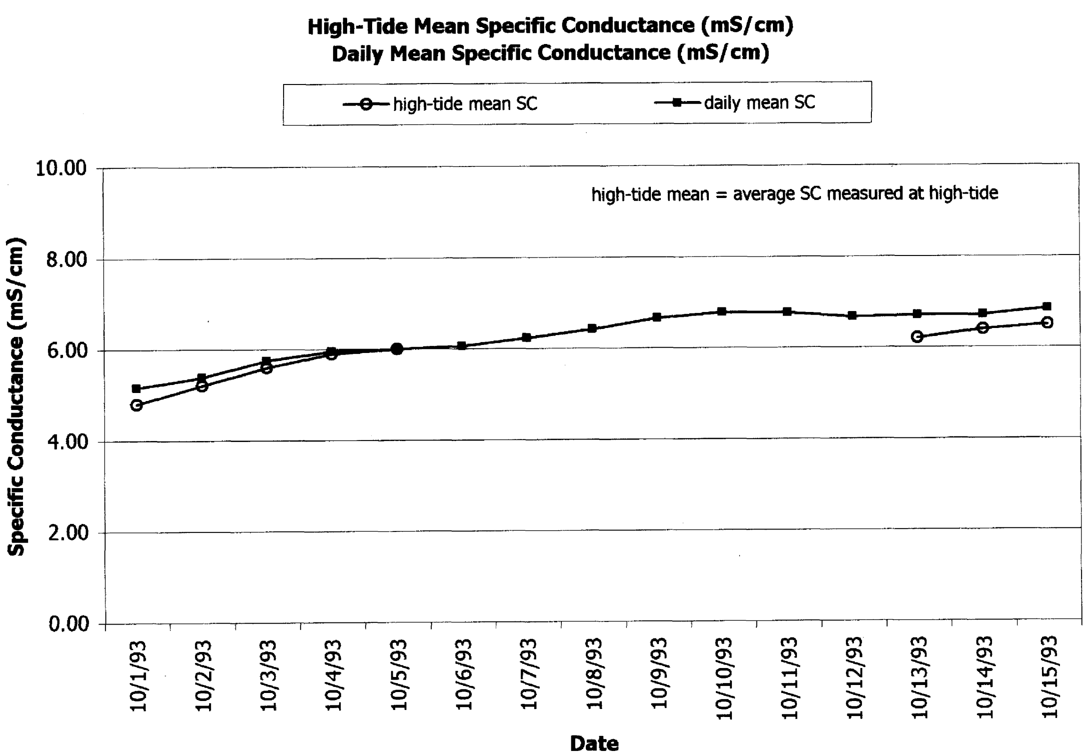
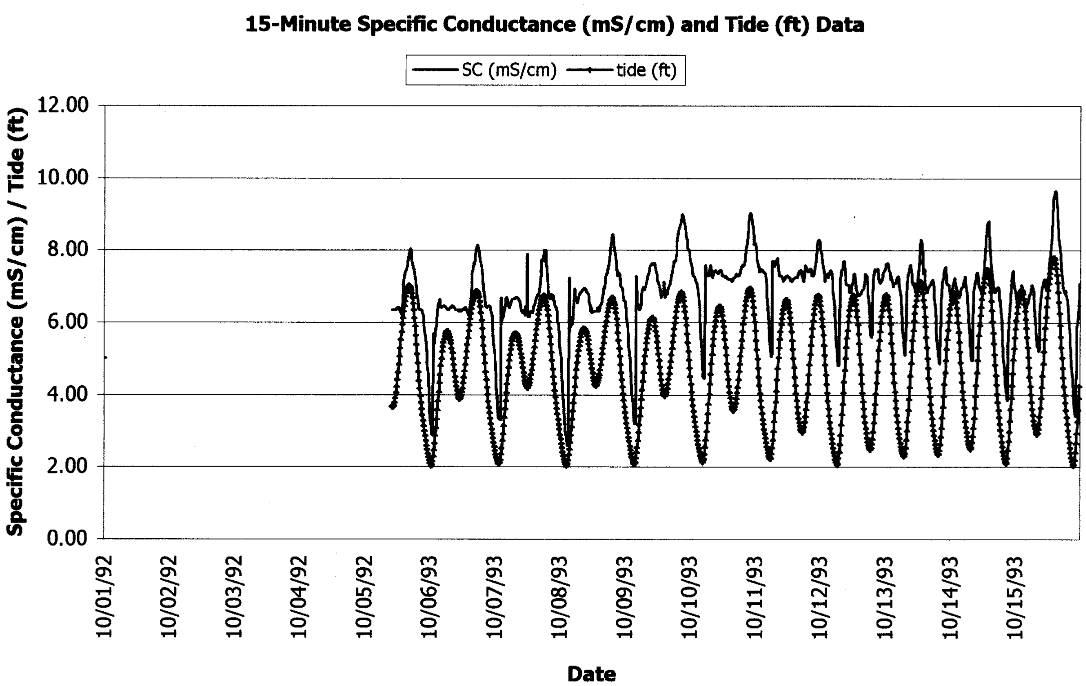


Figure 8 S-42 high versus mean tide salinity analysis from 1 to 15 October 1993



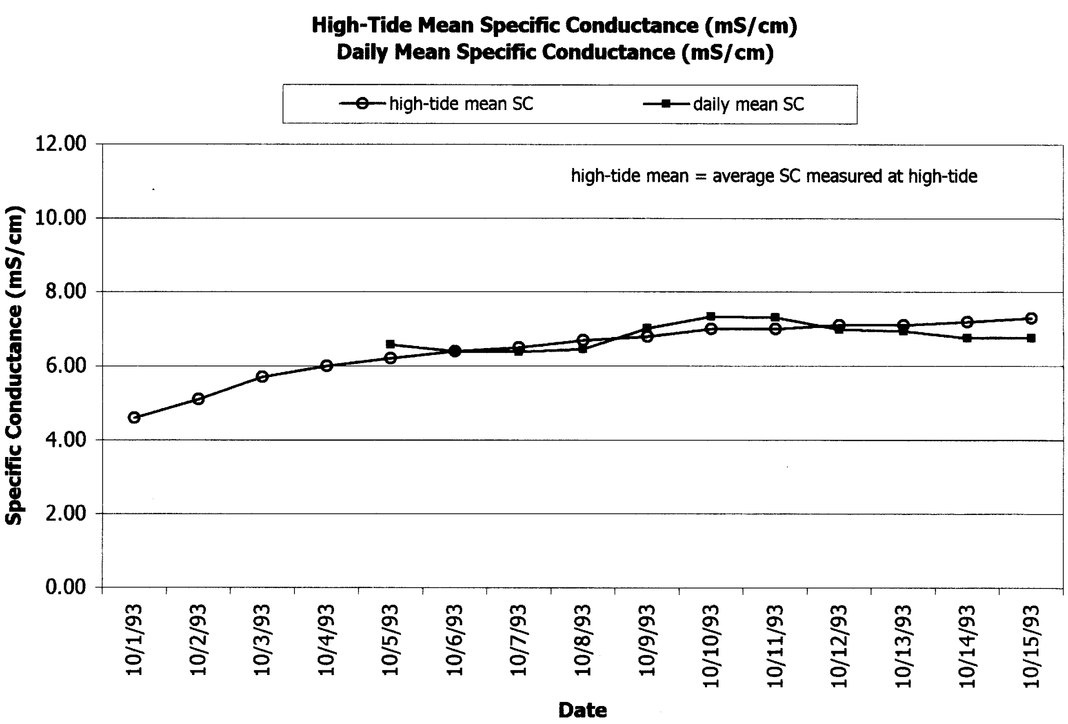
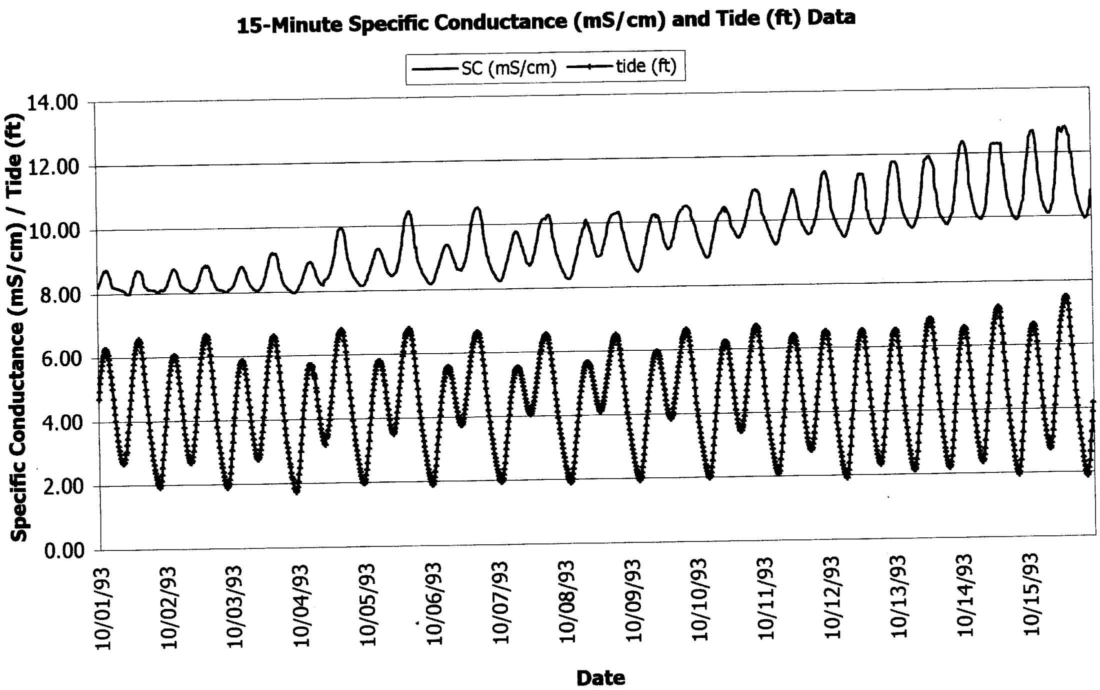


Figure 9 S-21 high versus mean tide salinity analysis from 1 to 15 October 1993



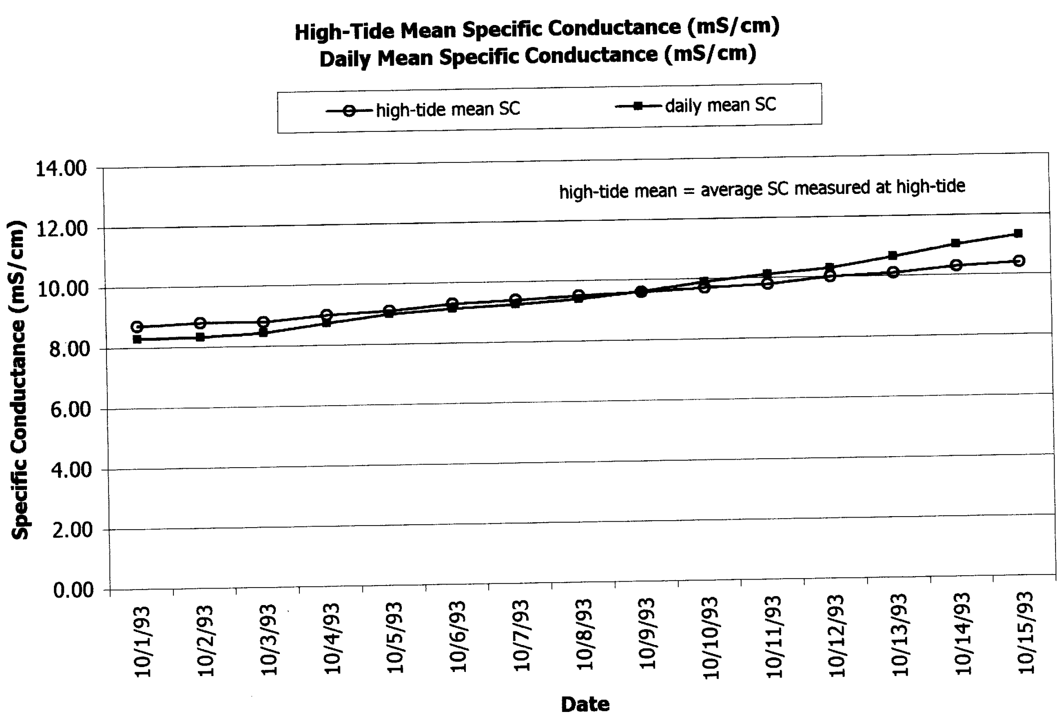


Figure 10 S-97 high versus mean tide salinity analysis from 1 to 15 October 1993

Delta Outflow

The Delta Outflow Index (DOI) is a calculated value defined as the sum of all flows and precipitation run-off minus all agricultural, municipal, and industrial diversions from the Delta. Since the DOI does not reflect daily tidal conditions and is, therefore, an inaccurate estimate of daily net outflow, a more accurate estimate is achieved by using simulation models to incorporate daily tidal fluctuations with the DOI. This measurement is called the Net Delta Outflow Index (NDOI). Both calculations are made over the 24-hour daily cycle (DWR 1995).

Delta outflow is the primary source of fresh water for Suisun Bay and Suisun Marsh. DWR and USBR increase DOI with releases from upstream reservoirs and decrease DOI when water is pumped from the Delta for export.

Local Creek Inflows

Several creeks originate in the watershed of Suisun Marsh including Green Valley, Suisun, Dan Wilson, Ledgewood, McCoy, and Denverton creeks. Local precipitation has its greatest effect on the Suisun Marsh in creek runoff. The influence of creek inflows is most significant in the northwestern marsh, where the sloughs are smaller and influences of Delta outflow and SMSCG operation are less pronounced. Suisun and Green Valley creeks have minimal base flows and respond quickly to watershed runoff. The other creeks are often dry, except during wet months (DWR 1995a).

Water Year Classifications

The NDOI is used, along with snow surveys and runoff predictions, to calculate and project the water year type on an annual basis. Water year classifications are determined using the Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index, shown in Figure 1 of D-1641[1].

Water year classifications in order of increasing runoff are critical, dry, below normal, above normal and wet. The water year classification affects which salinity standard is to be met in the Suisun Marsh.

Precipitation

Precipitation data are collected from the nearest National Weather Service station in Fairfield. Annual average precipitation at Fairfield from 1961 to 1990 was 21.4 inches (IAW Climatography of the US No. 81 for California).

1. Prior to water year 1996 water year classifications were determined based on the system in Table II of Decision 1485. In May 1995, SWRCB Water Quality Control Plan adopted the current water year classification system, which is used in D-1641.

Chapter 3
Historical Strategies for Seasonal Wetland Management

Habitat Goals for Managed Wetlands

The primary goal of most seasonal wetland management in Suisun Marsh is to provide habitat for waterfowl, and the fundamental component of that habitat is water. Wetland managers usually begin flooding their ponds with water from the sloughs and channels in early October, and drainage of the ponds begins after the waterfowl season ends in January. Most ponds in the Suisun Marsh are completely drained by June.

The second important component of good waterfowl habitat is vegetation, which provides food, shelter from the elements, and protection from predators. Wetland managers can manipulate the vegetation in their ponds through a variety of management techniques. Burning, discing, and mowing destroys or temporarily removes standing vegetation. Changing the flood duration (the number of days of standing water in the pond) affects both the growth of existing vegetation, and the germination of seeds in the soil. Each plant species has a range of tolerance for timing, duration, and depth of inundation.

Plant species also have soil water salinity tolerances, and there are several methods that can be employed to change the salinity of the soil water (a decrease is usually desired in Suisun Marsh). Circulating the water in the pond (an exchange of pond and channel water) acts to continually flush salts out of the soil. A rapid drain and fill of the pond is called a leach cycle, and this leaching can temporarily lower the salinity of the water in the first foot of soil. This technique is usually used in the spring to create favorable conditions for plant growth and seed-set.

Water and vegetation management are facilitated by effective, well-maintained water control structures such as intakes, drains, and circulation ditches. Rapid, complete drainage is important for salinity control, for if the water is not completely removed from the pond, or if the drainage period is too lengthy, the pond water becomes increasingly saline as it evaporates. The salt remains on the soil surface, contributing to high soil water salinity and high pond water salinity after flood-up the following October.

Although not an obvious goal of management, the actions of wetland managers arrest the ecological succession that occurs in natural wetlands. Many diked wetlands in the Suisun Marsh would gradually fill with tules or cattails if managers did not burn, disc, or employ water management actions to prevent this natural succession. Erosion and deposition are dynamic forces that act to change watercourses, elevation, and vegetative character of wetlands, and managers often work to suppress these actions and create more stable environments where they (the managers) are the primary agents of change.

Influential Studies of Waterfowl Food Plants and Environmental Effects

Habitat management and salinity standards in the Suisun Marsh have been strongly influenced by the results of several DFG studies conducted in the 1960s and 1970s.

- A waterfowl food habits study which examined the gizzard contents of ducks taken in Suisun Marsh determined that seeds from alkali bulrush (*Scirpus maritimus*), fat hen (*Atriplex triangularus*), and brass buttons (*Cotula coronopifolia*) provided the bulk of the winter waterfowl food supply (George and others 1965).

- Later studies (Mall 1969; Rollins 1973) on the habitat conditions necessary for these plants concluded that plant communities in the managed wetlands of Suisun Marsh are controlled primarily by the flood duration and secondarily by the concentration of salts in the root zone (usually the first foot of soil). The optimum flood duration was shown to be seven to eight months for alkali bulrush, and four to five months for fat hen. Salt concentration of 11 to 22 mS/cm in the root zone during May was found to be the most favorable salinity range for alkali bulrush seed production (Mall 1969).

Summaries of these works are presented in the following sections.

An Evaluation of the Suisun Marsh as a Waterfowl Area (from George and others 1965)

The vegetation study used color aerial photography, color interpretations, cover mapping, and planimetry to delineate and measure vegetation types. The results are shown in Table 1.

There are two serious limitations to the vegetation survey. The methods used to conduct the field verifications are not given, so it is not known how appropriate they were. Secondly, the report states that the vegetation types (see Table 1) were composites of several species dominated by the species for which the type was named, but the composition of the types is not given, except for the alkali bulrush type.

Table 1 Results of the 1960 Suisun Marsh Vegetation Survey (from George and others 1965)

Vegetation type	*Acreage*	*Percent of Cover*
Pickleweed	13,546	24.9
Salt grass	12,928	23.7
Annuals	5,862	10.8
Crops	4,379	8
Alkali bulrush	3,333	6.1
Tule	2,929	5.4
Cattail	2,476	4.5
Baltic rush	1,827	3.3
Brass buttons	1,128	2.1
Olneyi bulrush	521	1
Bare ground	262	0.5
Miscellaneous	5,307	9.7
Total	54,498	100

A soil study was done in conjunction with the vegetative survey. A total of 363 soil samples was collected from the 12 vegetation types identified in the vegetation survey. Soil samples were tested for specific conductance[2] (SC) and pH. There were several erroneous assumptions and conclusions associated with this soil study. The report states that, “soil salinity is the principal factor limiting the growth of marsh plants in Suisun Marsh.” No citation for this assumption was given, and it has not been substantiated by subsequent studies in the marsh. The researchers erroneously concluded that the two highest measurements of soil salinity for each vegetation type were representative of the “approximate level of salt tolerance for the species, beyond which it will not survive.” They also concluded that the samples collected from areas of bare ground “are beyond the limits of salt tolerance for all species of plants.” These two conclusions cannot be supported by the data, given the lack of data collected on other ecological factors affecting vegetation in the marsh.

The food habits study examined the contents of 1,408 stomachs (gizzards) of pintail (*Anas acuta*), mallard (*Anas platyrhynchos*), shoveler (*Spatula clypeata*), green-winged teal (*Anas carolinensis*), and wigeon (*Mareca americana*) ducks collected in Suisun Marsh during August, September, October and December 1960 and January 1961. Within each species, the frequency of occurrence and volume of each item were tallied as separate percentages. The average volume and average frequency of the five most common plant species found in the gizzards of each duck species are shown in Table 2.

Table 2 Results of waterfowl food habits study from 1959 to 1960 (from George and others 1965)

	Northern Pintail		*Mallard*		*Shoveler*		*Green-winged Teal*		*Widgeon*	
Species	*Averag e % Volume*	*Average % Frequency*	*Averag e % Volume*	*Average % Frequency*	*Averag e % Volume*	*Average % Frequency*	*Averag e % Volume*	*Average % Frequency*	*Averag e % Volume*	*Average % Frequency*
Alkali bulrush	37	76	30	71	42	89	30	78	6	41
Barley	8	19	18	31						
Brass buttons							16	41	5	12
Corn	12	17	10	10						
Fat hen	8	33	9	36			12	31		
Grass leafage									7	12
Pickleweed	4	19			11	48	5	27		
Pickleweed stem									35	47
Pickleweed seed									10	37
Sago			4	35	2	21				
Saltgrass					18	59				
Tule					3	34	9	53		

2. Electrical conductivity is the ability of a substance (water) to conduct an electrical current. Various ionic species in water, such as calcium, magnesium, sodium, chloride, sulfate, and carbonate, and their concentrations, directly affect the conductivity of water. Electrical conductivity also increases with temperature due to the increase in kinetic energy of ions in solution. Therefore, electrical conductivity provides an indirect measure of salinity at a given temperature of 25 degrees Celsius. Specific conductance is electrical conductivity corrected to a standard temperature of 25 degrees Celsius. Specific conductance is measured in mho/cm, which is electrical conductivity divided by the distance (usually 1 cm) between two platinum electrodes. Under the International System of Units conductivity is reported in Siemens/cm. Siemens and mhos are numerically equivalent. The unit milliSiemen (mS) is most often used in this report. Electrical conductivity and Electrical conductivity are used interchangeably throughout this report. All references to electrical conductivity in this report are actually specific conductance values.

This study noted that use of alkali bulrush had steadily increased from 8% in 1949 to 37% in 1961, and it was postulated that this increase was due to changes in water management by duck club owners to encourage the growth of alkali bulrush. However, the report included no data on acreage of alkali bulrush over this period.

This study concluded with a recommendation that landowners begin leaching their properties in the spring, because management that consisted only of flooding for duck season was increasing soil water salinities and was not producing significant amounts of waterfowl food.

Soil-Water-Salt Relationships of Waterfowl Food Plants in Suisun Marsh, California (from Mall 1969)

Food habits Study, Environmental Tolerances of Waterfowl Food Plants

Using the gizzard data from George and others (1969), Mall also analyzed waterfowl food habits, but reported results as Use (Frequency x Volume) and Selection (Use/Relative Abundance of the Plant), rather than George's Average Percent Frequency and Average Percent Volume. The relative abundance for plant species was calculated from the results of the 1960 plant survey discussed previously, and is defined as the percent of ground cover each plant contributed to the total plant cover in the Suisun Marsh (percent of cover from Table 1). Mall's results are shown in Table 3. Mall points out that the selection values based upon plant coverage falsely imply that each plant is available to and edible by ducks in proportion to its abundance in the marsh. It is interesting to note the substantial differences in the “top five” species of plants consumed by ducks in the two studies.

Table 3 Results of waterfowl food habits study from 1959 to 1960 (from Mall 1969)

	Northern Pintail		*Mallard*		*Shoveler*		*Green-winged Teal*		*Widgeon*	
Species	*Selection*	*Use*	*Selection*	*Use*	*Selection*	*Use*	*Selection*	*Use*	*Selection*	*Use*
Alkali bulrush	368	2,283	302	1,874	475	2,929	375	2,323	41	250
Barley	67	148	280	617						
Beard grass									47	80
Brass buttons	345	1416			13	53	182	748	42	172
Dock			51	155						
Fat hen			80	296			144	531		
Italian ryegrass	238	262								
Pickleweed					22	403	8	144	132	2,480
Saltgrass					82	2,117				
Tule			49	262	39	206	89	471		
Wild radish									72	72
Wiregrass	155	46								

The results of these two food habits studies may have over-emphasized the importance of alkali bulrush seed in the waterfowl diet. It is generally agreed (Swanson and Bartonek 1970; Miller 1987) that studies of gizzard contents do not reveal the true nature of the waterfowl diet. Hard, and sometimes indigestible, foods (such as seeds) are over-represented in the results, while soft foods (such as invertebrates, leaves, and stems) are under-represented because the digestive process renders them unidentifiable in the gizzard. In 1998 SRCD and the University of California, Davis (UC Davis) began a new food habits study involving the collection of esophagi of mallards, pintail, and green-winged teal for analysis to more accurately determine what these species are eating in the marsh.

In addition to the food habits study, Mall attempted to determine the effects of soil water salinity, length and depth of soil submergence, soil moisture, salinity of applied water, and soil organic matter on the distribution and growth of Suisun Marsh plants. These factors and plant growth were monitored at monthly intervals on quadrats within specific vegetative stands, and then end-of-season species composition was related to observed conditions. Mall concluded that the length of soil submergence had the greatest influence on the distribution of Suisun Marsh plants, and within the tolerances for submergence, the concentration of salts in the root zone determined the relative presence or absolute absence of a given plant species. The other variables measured did not appear to contribute any significant control. Spring soil salinity was found to control the amount of alkali bulrush seed produced, and seed production was maximized at May salinity levels of 7 to 14 ppt. This result was used in establishing the water quality standards in D-1485.

There are a number of weaknesses with Mall's findings, primarily that his results were site- and time-specific and not widely applicable to vegetation in the marsh. Mall's studies of the salinity tolerances of alkali bulrush did not include controlled experiments to determine the specific factors contributing to the results. Important physical and biological factors such as waterlogging, soil chemistry, nutrient availability, competition with other plant species, and interactions with animal species, were not measured.

Mall conducted his studies of plant salinity tolerances over just two years. Results of the DWR on-site monitoring program indicate that conditions change from year to year, and that two years of data are inadequate for drawing definitive conclusions about relationships between vegetation and environmental conditions. Mall pointed out that “most of the plants investigated were perennials and the current status and growth of such plants could have resulted from prior conditions that were different from those measured during this study.” A two-year study is inadequate to determine seed production, channel water salinity levels needed to maximize seed production, or to quantify “maximum seed production.” However, Mall did observe important relationships between above-ground growth patterns, flooding depth, and channel salinity, but these are probably applicable only at the actual study sites.

The graph shown in Figure 11 is from Mall's (1969) report and documents a very specific relationship between May soil water salinity, flood duration, and alkali bulrush seed production (on plots dominated by alkali bulrush). Mall states that multiple regression analysis was used to generate these curves, but he did not state which independent and dependent variables went into constructing the graph. Therefore, it is impossible to attempt to replicate his results, or to determine how well his data fit the curve in the graph. Without multiple regression, the data collected in the DWR on-site monitoring program show no correlation between flood duration, May soil water salinity, and seed production (Figures 12 and 13). These graphs reveal only that seed production drops off when May soil water salinity exceeds 30 mS/cm (19 ppt) and when flood duration exceeds 250 days.

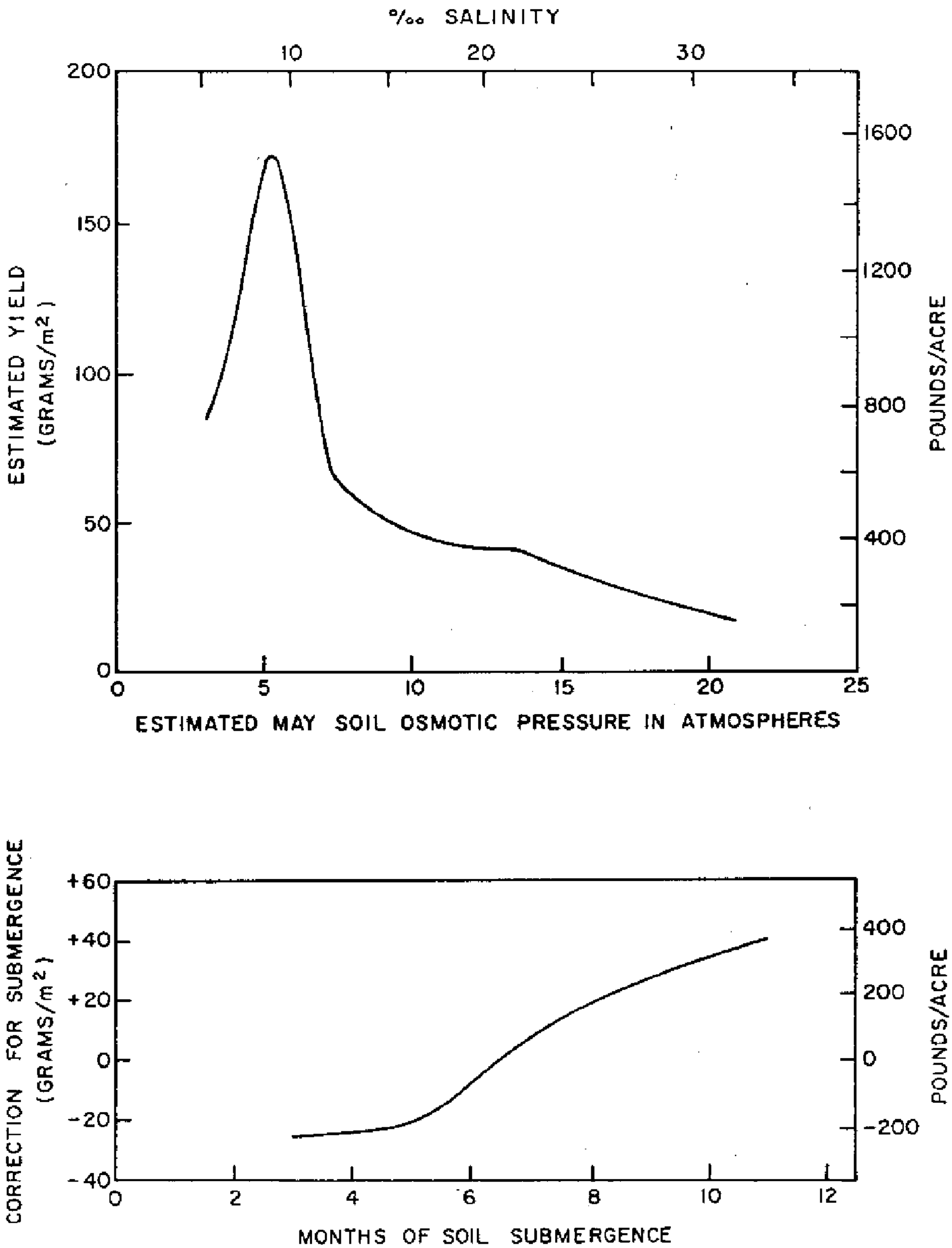


Figure 11 Multivariate analysis relationship between soil water salinity, flood duration, and alkali bulrush seed production (from Mall 1969)

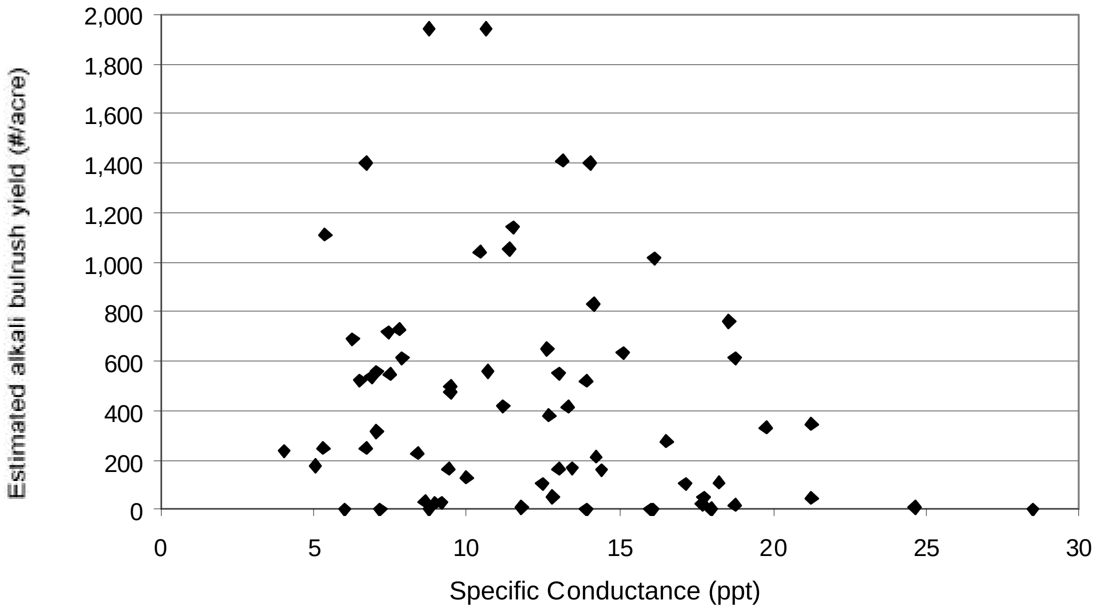


Figure 12 Alkali bulrush seed production and May soil water salinity. Data from Suisun Marsh Monitoring Program.

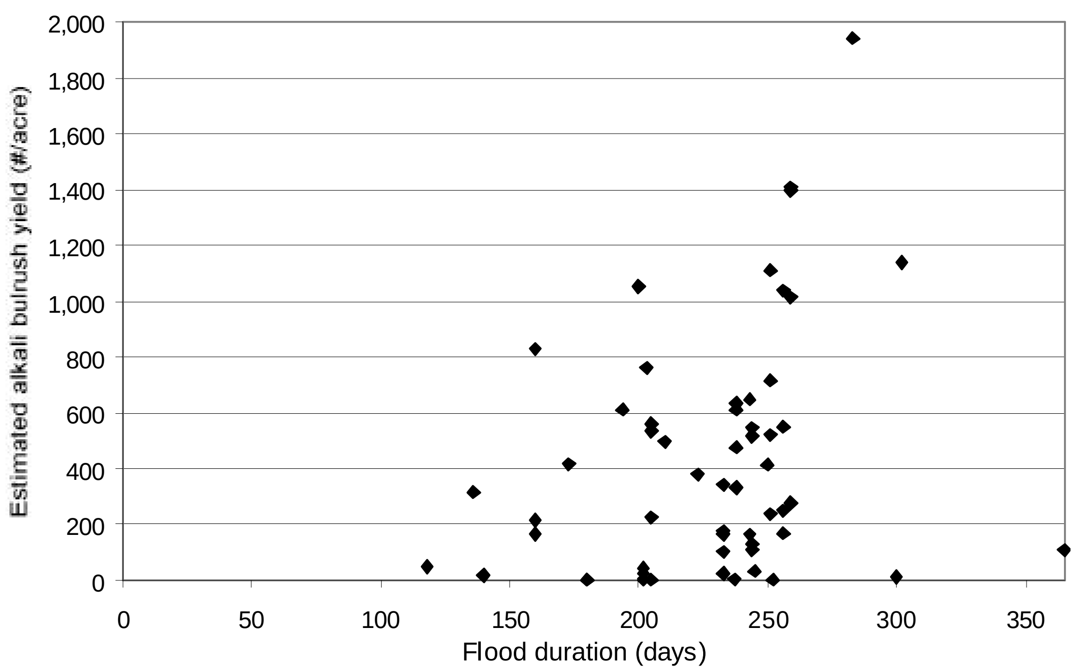


Figure 13 Alkali bulrush seed production and flood duration. Data from Suisun Marsh Monitoring Program.

Finally, the salinity standards developed from this study were established to protect levels of alkali bulrush seed production that are artificially high. This plant, which spreads primarily through underground rhizomes, does not naturally produce large amounts of seed (Adams 1990). It is not reasonable to assume that alkali bulrush will produce large quantities of seeds year after year, regardless of soil water salinity, for the plant does not depend on seeds for reproduction.

Relationships Between Soil Salinity and the Salinity of Applied Water in Suisun Marsh, California (from Rollins 1973)

A study by Rollins (1973) investigated the effects of applied water salinity on soil water salinity. Part 1 of the study measured soil water salinity on four duck clubs in the western marsh. Parts 2 and 3 were conducted on a small study pond where infiltrometers were used to apply water of known salinity to small plots. Part 2 was an “accelerated” study where salinity measurements over a few weeks were used to substitute for salinity over as many months. The experiments in Part 2 did not result in the high soil water salinities observed under natural conditions, so Part 3 used the same equipment and procedures as Part 2, but measurements were taken in real time.

At the time this study was done, it was suggested that, “as a result of upstream water diversions, the salinity of channel water in the Suisun Marsh in 1990 may be from two to three times greater in the late spring and early fall than it is at present.” (The research was done in 1967 and 1968.) There are few available records of salinity from 1967 through today, but information was found from a station located in Suisun Bay on the Contra Costa shoreline near Seal Island and the Concord Naval Weapons Station. Values from this station were used to chart late spring and early fall water salinity from 1967 to 1995 (Figures 14 and 15). Late spring values are a monthly average of daily values for May and June (see Figure 14), and early fall values are averages for September and October (see Figure 15). Although the graph does appear to show an increase over time, many of the later, high values are due to the 1987-1992 drought. Comparisons of similar water year types can be made with 1967, 1969, 1982, and 1995, which were all wet years following below normal (1967 and 1969), dry (1982), or critical years (1995) (see Figures 14 and 15). Values for 1995 are not appreciably higher than values for the other years. Comparisons were also made between 1971 and 1984, both wet years preceded by two wet years. The values are similar in the fall, but are almost three times higher in spring 1984 than in 1971. This discrepancy may be due to a lack of data for May and June 1984. There are no data available for May, and the June average was calculated from only ten daily values. However, full data sets are available for April (average 4,000 microSiemens/cm) and July 1984 (8,700 microSiemens/cm), and indicate that the June average (12,000 microSiemens/cm) may be non-representative. In conclusion, channel water salinity in the Suisun Marsh has not increased two- or three-fold in the thirty years since Rollins did his research.

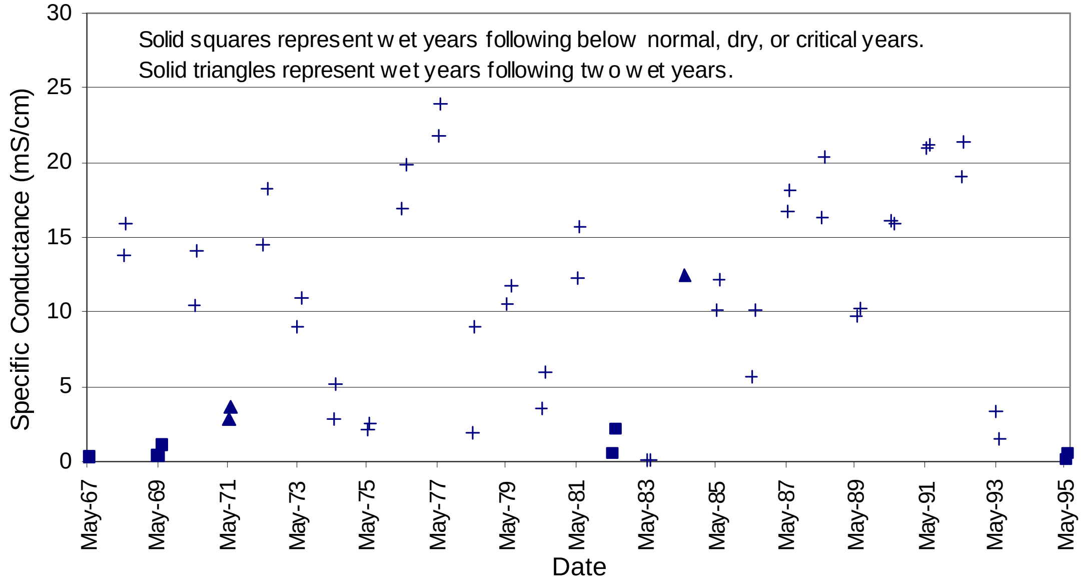


Figure 14 Specific conductance at Suisun Bay monitoring station RSAC64 in late spring (May and June) for water years 1967 through 1995

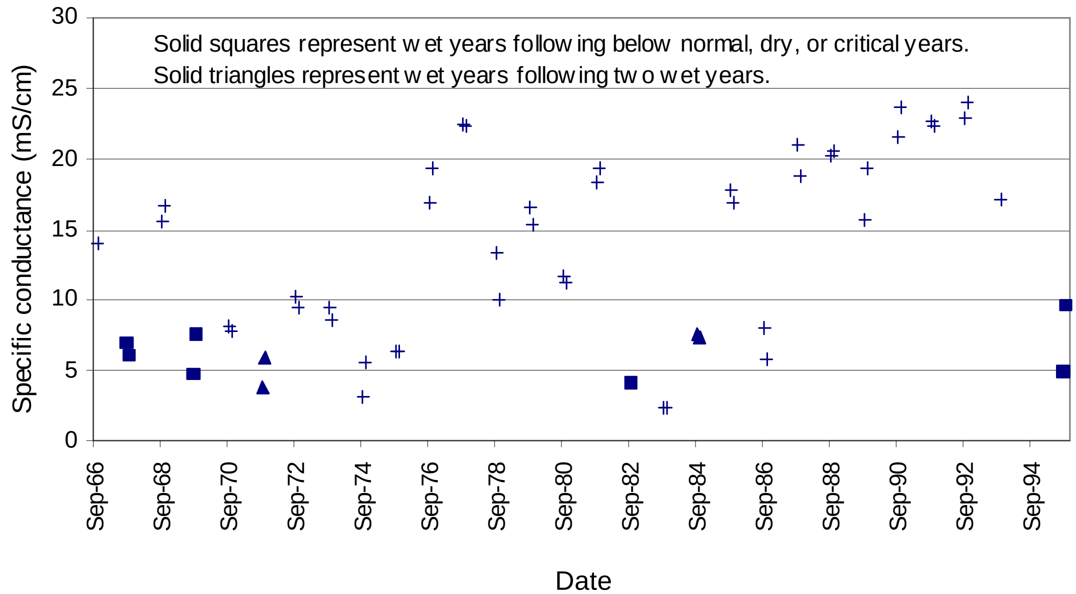


Figure 15 Specific conductance at Suisun Bay monitoring station RSAC64 in early fall (September and October) for water years 1967 through 1995

Table 4 Department of Fish and Game salinity guidelines for optimal alkali bulrush seed production

	Specific Conductance (mS/cm)	
Month	*Applied Water*	*Soil Water*
October	18.8	50.0
November	15.6	37.5
December	15.6	31.2
January	12.5	25.0
February	7.8	15.6
March	7.8	14.1
April	10.9	14.1
May	10.9	11 - 22

The results of the duck club study (Part 1) showed that soil type influenced percolation, drainage, and soil water salinity; water delivery ditches aided in speeding drainage and removing salts from the soil; flooding with low salinity water reduced soil water salinity; and when ponds were flooded only for waterfowl season, resultant soil salinity was too high to promote the growth of preferred waterfowl food plants.

From the results of the infiltrometer study (Parts 2 and 3), Rollins concluded that there was a statistically significant relationship between applied water salinity and the soil water salinity. In the graphs used to illustrate this relationship, salinity is charted as soil salt concentration, but much of the text refers to soil salt amount. Salt amount and concentration are not strictly comparable; the latter is dependent upon soil moisture. This and several other discrepancies between text and graphs that make it difficult to follow the reasoning to the conclusions. One result that is consistent throughout the report is the effect of leaching with low salinity water, which reduced soil water salinity. Rollins qualified this finding, however, by noting that his study pond was much smaller than any actual duck club pond and drainage was relatively efficient, and that water managers could not expect to see such dramatic results on their own ponds. Rollins recommended that a combination of improved management practices (including a spring leach cycle), improved drainage and control facilities, and a supplemental supply of fresh water were needed to attain desired soil conditions for waterfowl food plants.

Development of Early and Late Drawdown Management Plans

The research conducted by Mall (1969) and Rollins (1973) on the salinity tolerance of the plants identified by George and others (1965) as waterfowl food plants was used to establish the water quality standards in Decision 1485. The research identified maximum applied water salinities that would provide an average of 90% of maximum alkali bulrush seed production and a 60% seed germination rate. The DFG used these salinities as guidelines for long-term management and maintenance of wetlands in Suisun Marsh. Rollins (1981) found these guidelines to represent the most saline water that could be regularly applied to well-managed seasonal wetlands without loss of alkali bulrush seed production. According to these guidelines, wetland managers, when provided with water within the applied water salinity guidelines and adhering to the late drawdown management schedule (see below), should attain the soil water salinities in Table 4 (Rollins 1981).

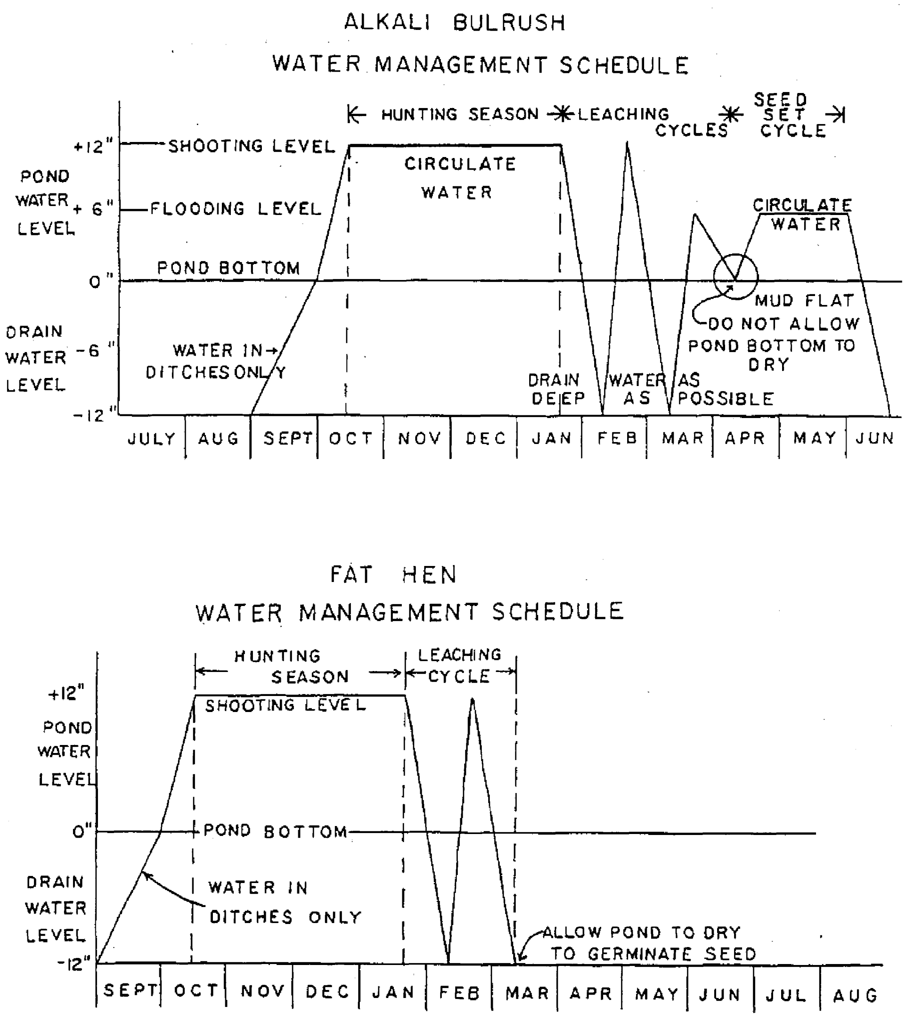


Figure 16 Water management regimes employed in Suisun Marsh (from Rollins 1981)

These findings were also used to establish management regimes to enable wetland mangers to grow large stands of alkali bulrush or fat hen. The late drawdown water management schedule (Figure 16, top) produces dominant stands of alkali bulrush and subdominant stands of fat hen and brass buttons while retarding the growth of plants such as tules, cattails, saltgrass, and pickleweed. The late drawdown schedule calls for the ponds to be leached twice after hunting season, then reflooded to one-half shooting depth (shooting depth is 8 to 12 inches), drained just to mudflat, reflooded to one-half shooting depth, and circulated in April and May to facilitate the seed-set cycle of alkali bulrush. Final drain occurs in early June, following circulation and seed-set (Rollins 1981).

The early drawdown water management schedule (Figure 16, bottom) was developed to produce stands of fat hen and brass buttons, while suppressing plants such as tules, cattails, and saltgrass. Fat hen management is only recommended for relatively level areas with well-drained soils and efficient water control facilities because without these conditions soil salinity may increase, creating conditions favorable to pickleweed. An early drawdown schedule requires that ponds be leached once to a depth of at least one foot below pond bottom following the end of hunting season. Subsequently, the ponds are flooded to shooting depth and drained completely by mid-March. Fat hen seedlings will only become established after the removal of surface water (Rollins 1981).

In the 1970s, using primarily the water management schedules outlined previously, the SRCD prepared water management plans for each of the privately managed wetlands in the marsh. In recommending water management schedules and improvements in both water and vegetation management, these plans took into account each ownership's mean pond bottom elevation, external (slough) tide elevation range, water control facilities, soils, and habitat goals. In the mid 1980s the SRCD recommended that the clubs periodically change their water management regimes to discourage the production of monocultures and increase diversity of wetland plants. The DFG prepared its own management plans for State-owned land in the marsh; these also relied heavily on the early and late drawdown schedules.

Management Regimes Practiced by Landowners During Monitoring Program

Most wetland managers of the Suisun Marsh begin flooding the ponds on 1 October in preparation for the fall migration of waterfowl. To reduce mosquito production in the Suisun Marsh, Solano County Mosquito Abatement District does not recommend flooding before 1 October, unless the landowner can flood and drain the wetlands within ten days or is willing to pay for mosquito control spraying.

When possible, wetland managers use gravity flow to fill and drain their ponds. Consequently, the ponds are filled during high tide when the water can flow through the inlet gates into the pond. Unfortunately, this means that the ponds are flooded when applied water salinity is at its highest. The ponds are drained during low tide when water elevation in the ponds is higher than that of the slough, and water flows out through drain gates and into the slough.

During initial flood-up in October, the inlet gates are opened and the drain gates remain closed to allow the ponds to fill to a depth of about 8 to 12 inches. After initial flood-up, water is diverted from adjacent sloughs, circulated and then drained while maintaining water at the 8- to 12-inch depth. Compared to the initial flood-up period, relatively small amounts of water are exchanged between the sloughs and the ponds during circulation. The circulation of water maintains water quality and prevents stagnant areas from developing. Circulation also helps prevent an increase in pond water salinity resulting from evaporation, and helps to maintain natural soil water salinity. Typically, the ponds are dewatered in late January to begin management activities.

Production of a diverse assemblage of wetland vegetation requires managers to base their management on factors such as soil water salinity, depth, and duration of soil submergence, and applied water salinity. Appropriate management, including circulation and leaching, is required to prevent increases in soil water salinity above natural levels for Suisun Marsh soils, as outlined by the USDA Soil Conservation Service (1977). Leaching usually begins in February and can take from one to four months, depending on the water management schedule being implemented. Final drainage of the ponds occurs between March and June to allow vegetative growth and to perform necessary maintenance activities during the summer.

NMFS and USFWS have imposed water diversion restrictions on unscreened diversion in the Suisun Marsh to avoid adverse effects to delta smelt, winter-run chinook salmon, and other resident and anadromous fish populations. Therefore, implementing these water management schedules often cannot be achieved. Effective maintenance of soil salinities may not occur on properties with the diversion restrictions in place, unless a fish screen has been installed. By 1998, the SRCD Diversion Screening Program had installed 12 screens on private intakes.

During the course of this monitoring program, many different water management scenarios were practiced by the landowners in the Suisun Marsh. Monitored ownerships rarely applied the same water management each year of the program. The most common practice was for the ponds to be flooded for waterfowl season and then drained between March and June with no leach cycles (flood duration between 150 and 250 days). Landowners' attempts to adhere to either the early or late drawdown regime as outlined by Rollins (1981) met with varying degrees of success. These complex management regimes have strict guidelines for timing of fill and drain periods, duration of flooding, timing and depth of leaching, and periods of circulation; making it very difficult to adhere to these requirements. Despite Rollins' (1981) recommendation to use leach cycles to decrease soil water salinity, only half of the monitored ownerships regularly (at least 40% of the time) used this practice.

Problems Associated with Management of Diked Wetlands

In tidal wetlands, the soil is always moist and the presence of water in the soil and the flushing action of the tides keep the salt concentration at fairly constant levels. The building of dikes isolated the marshlands from daily tidal action and the leaching effects of winter fresh water flooding. Management of these diked ponds for waterfowl habitat has typically included initial flood-up in the fall (when the water in Suisun Marsh channels is often near its annual maximum), drainage after the end of waterfowl season, and leaving the ponds dry through the summer. These months of dry conditions cause the salinity of the soil water to increase as water is lost through evaporation and saline water is drawn up from below. Soil water salinity decreases when the ponds are flooded again in the fall, but salts can build up in the soil profile, causing an increasing trend in salinity. Soil water salinity can increase to concentrations that are toxic to plants, leaving salt-scalded bare ground. Drying the ponds during the summer months also leads to other adverse changes in the soil, including soil shrinkage and cracking, collapse of clay lenses (Miller and others 1975), and acidification of the soil from the formation of sulfuric acids and sulfates in the soil. Some ponds in the Suisun Marsh are subsiding because the levees prevent deposition of silt, and discing or burning of vegetation can slow down peat formation.

However, the greatest concern of Suisun Marsh landowners is high soil water salinity. Many studies in the Suisun Marsh have stated that when brackish or saline wetlands are diked, flooded with saline water, and kept dry for part of the year, the result is increased soil water salinity (DPW 1931a; George and others 1965; Mall 1969). These studies have advised managers to circulate water in the ponds and to leach in the spring with low salinity water to decrease soil salts.

In addition, landowners in the Suisun Marsh have tried to create conditions favorable to plant species (alkali bulrush, fat hen, brass buttons) that were not historically abundant in the Suisun Marsh and to minimize the two historically most common species (salt grass and pickleweed). George (1965), in a discussion of water management practices, stated that, “pickleweed and salt grass dominate those area where poor water manipulation is practiced, whereas most of the stands of alkali bulrush occur where the water is manipulated to its advantage.” It is important to note that despite large scale water projects and diversions, and less-than-ideal water management in the Suisun Marsh, the managed wetlands of the Suisun Marsh have remained productive and vegetatively diverse.

Chapter 4
Legislative and Administrative Actions

This chapter summarizes the history of relevant legislative and administrative actions on the Suisun Marsh.

Formation of Suisun Resource Conservation District

In 1963, the SRCD was formed by private landowners in Suisun Marsh. SRCD was developed to perform administrative, regulatory and technical functions that include representing landowner interests, both individually and collectively; obtaining environmental permits for routine maintenance activities; preparing wetland management plans for all private lands within the district; and providing technical expertise on issues related to Suisun Marsh management. The district includes 52,000 acres of managed wetlands, 6,300 acres of unmanaged tidal wetlands, 30,000 acres of bays and sloughs, and 27,700 acres of upland grasslands. There are 158 privately owned duck clubs in the Suisun Marsh, and DFG manages about 15,000 acres of the managed and tidal wetlands.

1970 Memorandum of Agreement

On 13 July 1970, a Memorandum of Agreement was signed by the USBR, the US Fish and Wildlife Service (USFWS), DWR and DFG. One of the goals of this agreement was to select a water supply and Suisun Marsh management plan that would protect and enhance waterfowl habitat (USFWS 1981).

1974 Suisun Marsh Preservation Act

The California Legislature, recognizing the threat of urbanization to Suisun Marsh, enacted the Nejedly-Bagley-Z'berg Suisun Marsh Preservation Act of 1974 (Senate Bill 1981). The act required the DFG and the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan to protect the Suisun Marsh. In December 1975, the DFG released the Fish and Wildlife Element of the Suisun Marsh Protection Plan (Jones and Stokes and EDAW 1975), which contains an inventory of fish and wildlife species found in and around the Suisun Marsh, an interpretation of how the Suisun Marsh functions, and recommendations for protection of the Suisun Marsh.

1976 Suisun Marsh Protection Plan

In 1976, the BCDC submitted the Suisun Marsh Protection Plan to the California Governor and Legislature (SFBCDC 1976). The Suisun Marsh Protection Plan divided the Suisun Marsh into primary and secondary management zones based on land use. Tidal wetlands and diked lands managed as wetlands were placed in the primary management zone; uplands and lands adjacent to the Suisun Marsh were classified as the secondary management zone. The purpose of the secondary management zone is to provide a buffer between urban development and wetland areas of the Suisun Marsh. Under the Suisun Marsh Protection Plan, the BCDC serves as the permitting agency for all major projects within the primary management zone and as an appellate body with limited functions in the secondary management area. The Suisun Marsh Protection Plan recommended that local agencies develop a plan of compliance, recommended and prioritized the acquisition of properties, proposed a tax assessment plan based on land use, and identified both State and federal sources of funding to achieve its objectives.

Assembly Bill 1717

In 1977, the California Legislature passed Assembly Bill 1717, which added the Suisun Marsh Preservation Act of 1974 to the Public Resources Code and implemented the recommended protection measures outlined in the Suisun Marsh Protection Plan. This act emphasized the importance of the Suisun Marsh as a unique and irreplaceable resource, particularly because of the habitat available for wintering waterfowl.

1978 Water Right Decision 1485

In August 1978, the State Water Resources Control Board (SWRCB) adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh (SWRCB 1978a). At the same time, the SWRCB issued Water Right Decision 1485 (D-1485), which implemented the standards in the Water Quality Control Plan (SWRCB 1978b). D-1485 set channel water salinity standards for Suisun Marsh from October through May to preserve the area as a brackish water tidal marsh and to provide optimum waterfowl food plant production. D-1485 placed operational conditions on water right permits for the Central Valley Project (CVP) and State Water Project (SWP). Order 7(a) of D-1485 required the permittees to develop and fully implement a plan, in cooperation with other agencies, to ensure that the salinity standards are met.

In D-1485 Order 7(b), SWRCB directed USBR and DWR to develop and implement a plan by October 1, 1984, to protect the Marsh. In February 1984, DWR submitted the Plan of Protection for the Suisun Marsh, but was not able to implement the plan by the 1984 deadline. In the meantime, DWR and USBR provided partial mitigation through Initial Facilities constructed pursuant to Order 7(c) of D-1485 and through the December 1978 contract (discussed below) among SRCD, DFG, and DWR.

1978 Agreement for the Initial Facilities

In December 1978, DWR, DFG, and SRCD signed an agreement defining responsibility for construction, operation, and maintenance of the Initial Facilities. The purpose of the Initial Facilities[3] was to partially restore and maintain the Suisun Marsh as a brackish water marsh capable of producing high-quality food and habitat conditions for waterfowl and other marsh wildlife. The Initial Facilities were intended to partially mitigate the adverse effects on the Suisun Marsh of operations of the SWP and CVP.

The purpose of the agreement was to partially define the responsibilities of DWR to mitigate for the effects of increased salinity levels of water available to certain managed wetlands of the Suisun Marsh. The agreement states, among other things, that DWR shall design, construct, operate, and maintain the Initial Facilities solely at its expense (or in cooperation with USBR) and in compliance with applicable laws.

3. Initial Facilities consist of Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall.

1984 Plan of Protection for Suisun Marsh

In 1984, DWR published the Plan of Protection for Suisun Marsh including an Environmental Impact Report, prepared in cooperation with DFG, SRCD, and USBR in response to D-1485 Order 7. The USFWS also provided significant input. The Plan of Protection was a proposal for staged implementation of a combination of activities including monitoring, a wetlands management program for Suisun Marsh landowners, physical facilities, and supplemental releases of water from CVP and SWP reservoirs. With staged implementation, each action would be evaluated to determine the need for subsequent actions.

The Initial Facilities and the Suisun Marsh Salinity Control Gates (SMSCG) have been constructed and are being operated. Planning and environmental documentation for Phases III and IV (western Suisun Marsh) were also conducted from 1990 to 1995. However, the four parties agreed that the additional large-scale facilities described in the Plan of Protection and the Suisun Marsh Preservation Agreement (or equivalent actions) are not necessary for salinity control in Suisun Marsh because of the effective operation of the SMSCG and the increased outflows provided under the 1994 Principles of Agreement and the 1995 Water Quality Control Plan (described in the following sections). Instead, the parties are developing an Amendment to the SMPA (discussed in the following sections).

1985 Amendment to D-1485

In 1985, the SWRCB modified Table II of D--1485 to extend the effective dates and location criteria of the Suisun Marsh channel water standards. The revised effective dates for the standards, beginning October 1 of each specified year, follow:

- 1988 at C-2, S-64, S-49.
- 1991 at S-21 and S-33 **or** 1993 at S-21 and S-97[4].
- 1991 at S-35 **or** 1994 at S-75[5].
- 1997 at S-42 and water supply intake locations for waterfowl management areas on Van Sickle Island and Chipps Island.

The 1985 implementation schedule recognized the planned phased construction described in DWR's 1984 Plan of Protection for the Suisun Marsh (discussed below).

1987 Suisun Marsh Preservation Agreement

On 2 March 1987, DWR, DFG, USBR, and SRCD signed the Suisun Marsh Preservation Agreement (SMPA) to mitigate for effects on Suisun Marsh salinity from the CVP, SWP, and other upstream diversions (USBR and others 1987). The objectives of the original SMPA remain the same today as in 1987. These objectives are as follows:

4. DWR and USBR elected for S-21 and S-97.
5. DWR and USBR elected for S-75, but in 1994 they requested to move the location to S-35 due to problems with establishing the S-75 location.

- To assure that USBR and DWR maintain a water supply of adequate quantity and quality for managed wetlands within the Suisun Marsh. This is to mitigate adverse effects on these wetlands from operation of the CVP and SWP and a portion of the adverse effects of other upstream diversions.
- To improve Suisun Marsh wildlife habitat on these managed wetlands.
- To define the obligations of USBR and DWR necessary to assure the water supply, distribution, management facilities, and actions necessary to accomplish these objectives.
- To recognize that water users in the Suisun Marsh (in other words, existing landowners) divert water for wildlife habitat management within the Suisun Marsh.

To meet these objectives, the original SMPA established channel water salinity standards similar to those in D-1485 and a schedule for construction of large-scale facilities in Suisun Marsh that would enable the salinity standards to be met. USBR and DWR had responsibility for funding and constructing the facilities and for meeting the salinity standards. Construction of the facilities was to be in phases, based on evaluation of need and effectiveness of the facility previously constructed.

As required by the SMPA, DWR and USBR constructed the Suisun Marsh Salinity Control Gates in 1988. They constructed the Cygnus Unit in 1991, and the Lower Joice Island Unit in 1993 (Figure 17). These were in addition to the Initial Facilities constructed in 1980: Morrow Island Distribution System, Roaring River Distribution System, and the Goodyear Slough Outfall. In 1990, the two agencies began planning the Western Suisun Marsh Salinity Control Project, which was intended to fulfill Phases II and IV of the Plan of Protection. The objective of the project was to develop facilities or activities in the western Suisun Marsh that would compensate for the higher channel salinities in that area of the Suisun Marsh.

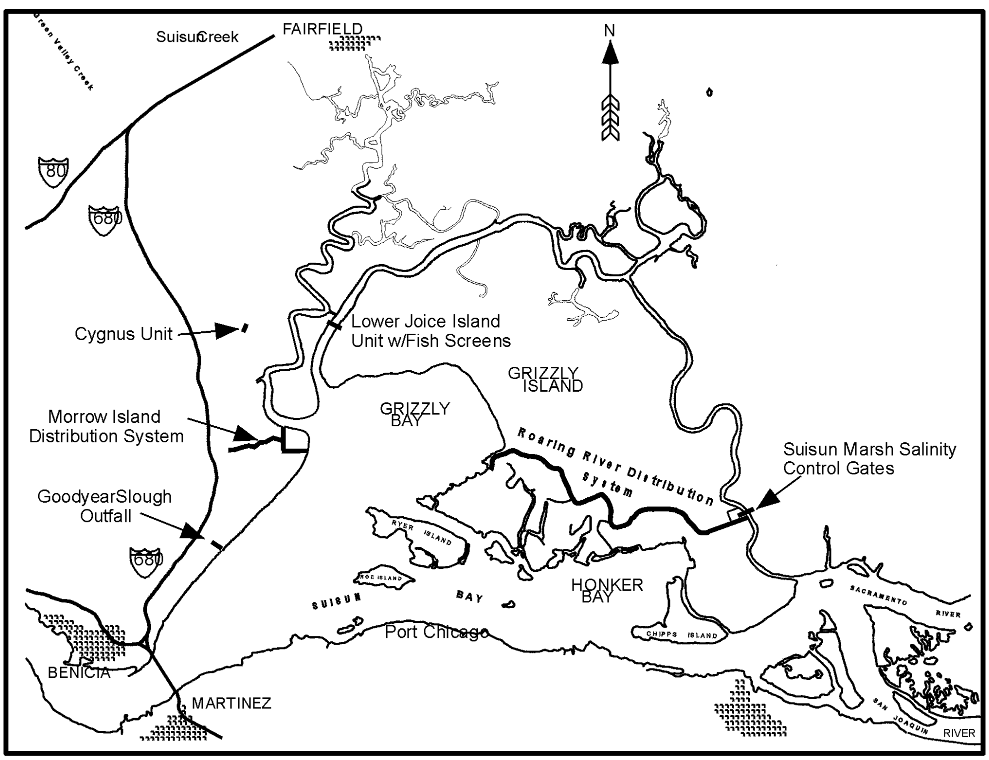


Figure 17 Suisun Marsh Physical Facilities

DWR and USBR stopped work on planning and environmental documentation for the western Suisun Marsh Salinity Control Project in April 1995 because of the increased outflows and the effective operation of the Suisun Marsh Salinity Control Gates.

Suisun Marsh Monitoring Agreement and Mitigation Agreement

DWR, USBR, and DFG also signed two companion agreements on 2 March 1987, the Suisun Marsh Mitigation Agreement and the Suisun Marsh Monitoring Agreement (DWR and others 1987a, 1987b). The Mitigation Agreement requires acquisition, development, operation, and maintenance of mitigation lands to offset loss and degradation of wildlife habitat resulting from construction of SMPA facilities and effects of the CVP, SWP, and other upstream diverters on the channel islands. The Monitoring Agreement requires implementation of the monitoring program described under the Plan of Protection for Suisun Marsh. The SMPA references the Mitigation Agreement and Monitoring Agreement and incorporates their requirements.

1991 Water Quality Control Plan

In May 1991 the SWRCB adopted the 1991 Water Quality Control Plan for Salinity, which set new objectives for salinity, dissolved oxygen and temperature for protection of fisheries-related and agricultural supply beneficial uses. The plan did not include flow and operation requirements needed to improve protection of fisheries-related beneficial uses. Therefore, in September 1991 the U.S. Environmental Protection Agency (USEPA) disapproved parts of the plan, believing it did not provide adequate protection for the estuarine habitat and other designated fish and wildlife uses of the Bay-Delta Estuary. The disapproved objectives remained in effect until January 1994, when the USEPA published draft standards for protection of fisheries-related beneficial uses in the Bay-Delta Estuary.

1994 Principles for Agreement on Bay-Delta Standards

In December 1994, State and federal agencies signed the Bay-Delta Accord, also called the Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government. Participating agencies included the U.S. Environmental Protection Agency, the National Marine Fisheries Service, The Bureau of Reclamation, the U.S. Fish and Wildlife Service, the California Resources Agency, the Department of Water Resources, the Department of Fish and Game, the California Environmental Protection Agency, and the State Water Resources Control Board. The Accord consisted of four components: 1) establishment of the CALFED Bay-Delta Program dedicated to developing a long-term ecosystem approach to solving issues in the Delta; 2) establishment of the Ops Group, a decision making group within CALFED; 3) a commitment by the water user community to fund $10 million annually for three years for non-flow related ecosystem restoration activities to improve the health of the Bay-Delta ecosystem; and 4) final USEPA water quality standards for the Bay-Delta, as well as interim State standards proposed by the SWRCB. The standards consisted of four parts: 1) salinity criteria in Suisun Bay; 2) survival targets for young migrating chinook salmon; 3) salinity criteria to protect fish spawning grounds on the lower San Joaquin River; and 4) narrative criteria for the Suisun Marsh tidal wetlands.

Decision to Amend the Suisun Marsh Preservation Agreement

In July 1995, a DFG, DWR, USBR, and SRCD Negotiation Team convened to begin updating the SMPA, pursuant to Articles 4, 8(h), and 17 of the original SMPA. This decision was based on changed conditions resulting from effective operation of the Suisun Marsh Salinity Control Gates and increased Delta outflows under the 1995 Water Quality Control Plan. The proposed SMPA Amendment Three is the outcome of these negotiations.

The SMPA was previously amended on two occasions. The first amendment was signed in 1988 and resulted in changes in the S-21 monitoring station location and in the construction schedule for the Cygnus and Lower Joice Island facilities. The second amendment was signed in 1994 and resulted in a change in the Individual Ownership Cost Share Program (Article 7) from a 50% to a 75% cost-share reimbursement by DWR and USBR to the landowners.

Based on analysis of several years of hydrodynamic and salinity modeling and water quality data collected in the Suisun Marsh, DWR and USBR concluded that SWP and CVP operations and other diversions upstream of Chipps Island have not significantly affected flow or water quality patterns in creeks north and west of Suisun Marsh (DWR and others 1994a). However, urbanization and land development north and west of the Suisun Marsh do significantly affect the pattern of creek inflow, sediment, and water quality entering the Suisun Marsh. Also, data collected from private and public managed wetlands indicate that water management plays a pivotal role in achieving soil water salinity and habitat goals (DWR Data Summary Reports 1992-1994). In addition, a prolonged drought, such as the one in 1987 through 1992, was not contemplated when the deficiency standards (allowing higher salinity) were included in the Original SMPA. Thus, the original SMPA does not adequately address effects to managed wetlands under drought conditions.

The decision was made to amend the SMPA, because of the reasons listed previously, and because hydrologic conditions in Suisun Marsh have changed since the original SMPA was signed in 1987. The amendment would make the channel water salinity standards consistent with the SWRCB's 1995 Water Quality Control Plan, and replace additional large-scale facilities with water and land management activities to meet the objectives of the SMPA in the western Suisun Marsh. Amendment Three requires amending the Monitoring Agreement to include monitoring required by the new actions and to include SRCD as a participant in the monitoring program. It also requires amending the Mitigation Agreement to broaden remaining mitigation activities and funds to include restoration of tidal wetlands and multi-species management.

In September 1995, the SMPA Negotiation Team established a Technical Support Group (comprised of technical staff from the four agencies) to provide data analysis, model studies, and technical input. In January 1996, the Negotiation Team requested that the Technical Support Group identify alternative actions needed to meet the objectives of the SMPA in the western Suisun Marsh. The Technical Support Group prepared a decision matrix of 21 actions, ten of which are included in Amendment Three. Informal consultations with USFWS resulted in preparation of a Biological Assessment for the Amendment, a draft of which was released in February 1999. Formal Section 7 consultation will commence upon completion of a Final Biological Assessment.

In a related but separate process, the SWRCB has included the joint actions proposed in this amendment as an alternative in the Draft Environmental Impact Report it has prepared for a water rights hearing to implement the 1995 Water Quality Control Plan.

1995 Water Quality Control Plan

In May 1995, the SWRCB adopted the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB 1995). The purpose of this plan is to establish water quality control measures that contribute to protection of beneficial uses in the Bay-Delta Estuary. The plan consists of the following:

- Beneficial uses to be protected.
- Water quality objectives for reasonable protection of beneficial uses.
- A program of implementation for achieving the water quality objectives.

Together, the beneficial uses and the water quality objectives established to protect them are called "water quality standards" under the terminology of the federal Clean Water Act. This plan supersedes both the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh adopted in August 1978 and the Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta adopted in May 1991. The SWRCB is to review this plan every three years to ensure that it adequately protects beneficial uses. The SWRCB will implement this plan principally through adoption of a water right decision.

1995 Water Rights Order WR 95-6

On 28 February 1995, DWR and USBR filed a joint petition requesting changes in the water rights that authorize diversion and use of waters affecting the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. In April 1995, the SWRCB held a public hearing and received evidence on the key issues listed in the notice. It was decided that Order 95-6 would be an interim order. Its Amendments are to expire upon adoption of a comprehensive water right decision that allocates final responsibilities for meeting the 1995 Bay-Delta objective or on 31 December 1998, whichever comes first. Order 95-6 replaced the water quality standards for fish and wildlife set forth in D-1485. All other provisions of D-1485 remain in full force and effect.

In June 1995, upon adoption of Order 95-6, SWRCB modified some of the terms and conditions imposed by D-1485 so they conform with new fish and wildlife standards for the estuary set forth in the December 1994 Accord and the 1995 Water Quality Control Plan. Order 95-6 modified the D-1485 Suisun Marsh channel water salinity standards, as revised in 1985, to allow for more saline conditions in the western Suisun Marsh during dry conditions, defined as the "Deficiency Period." The order also changed the effective compliance date for two western Suisun Marsh compliance stations to 1 October 1997 (Attachment B of Order 95-6, 8 June 1995). Compliance dates for other Suisun Marsh stations did not change.

1999 Water Rights Decision 1641

In December 1999, the SWRCB issued Water Rights Decision 1641 to implement the water quality objectives in the 1995 Bay-Delta Plan covered in phases 1-7 of the Water Rights Hearings. Decision 1641 supersedes SWRCB Orders WR 98-8 and 95-6. Decision 1641 implements the Suisun Marsh channel water salinity objectives contained in the 1995 Bay-Delta Plan. However, D-1641 removes the requirement to meet the water quality objectives at S-35, S-97, and water supply intakes on Chipps and Van Sickle Island, and instead requires baseline monitoring at these stations. Decision 1641 defers action on the narrative objective for unmanaged tidal marshes until the next periodic review of the 1995 Bay-Delta Plan, when a final report from the Suisun Ecological Workgroup should be available for review.

Other SWRCB Orders and Resolutions

In addition to the Decisions and Orders mentioned previously, the SWRCB has issued orders and resolutions to DWR waiving or extending compliance with water quality standards in Suisun Marsh (Table 5). Condition 6 of D-1485[6] allows for variations in flows for experimental purposes. Under this provision, the SWRCB has granted DWR waivers for various studies in the Marsh, including testing of the effectiveness of the SMSCG and Green Valley Creek flow augmentation, and effects of the SMSCG on salmon migration.

In September 1997, DWR and USBR petitioned the SWRCB for an extension of the effective compliance date for the two western Suisun Marsh compliance stations. In support of the extension, DWR prepared the Demonstration Document (DWR and others 1998), which demonstrates how management actions in SMPA Amendment Three would provide equivalent or better protection than meeting channel water salinity standards at far western Suisun Marsh stations. The SWRCB issued an order approving a temporary change of effective date for compliance through April 1998. DWR and USBR petitioned, and were granted, additional extensions through April 24, 2000.

Suisun Ecological Workgroup

The Suisun Ecological Workgroup (SEW) is an ad hoc multi-agency and multi-organizational technical work group convened at the request of the SWRCB, as a component of the Program of Implementation in the 1995 Water Quality Control Plan. SEW was convened to address the uncertainty of the effectiveness of the 1995 Water Quality Control Plan delta outflow objectives on tidal wetlands. The workgroup plans to provide a final report to SWRCB by July 2000.

According to the Program of Implementation, SEW is charged with the following objectives:

1. Evaluate the beneficial uses and water quality objectives for the Suisun Bay and Suisun Marsh Ecosystem.

2. Assess the effects on Suisun Bay and Suisun Marsh of the water quality objectives in the Draft Water Quality Control Plan and the federal Endangered Species Act biological opinions.

3. Identify specific measures to implement the narrative objective for tidal brackish marshes of Suisun Bay and make recommendations to the SWRCB regarding achievement of the objective and development of numeric objectives to replace it.

4. Identify and analyze specific public interest values and water quality needs to preserve and protect the Suisun Bay/Suisun Marsh ecosystem.

6. D-1641 amended this condition slightly; however, there were no substantial changes in the intent of the condition.

Table 5 Chronology of State Water Resources Control Board water quality actions in Suisun Marsh

SWRCB Action	*Date*	*Substantive Effect for Suisun Marsh*	*Purpose*
Decision 1485	8/78	Water quality objectives at all monitoring stations (C-2, S-64, S-48, S-42, D-7, S-31, S-35, and S-32) effective on 10/1/94	Establishes water quality objectives and water quality monitoring program for Suisun Marsh
Order	12/5/85	Amends compliance dates for Suisun Marsh standards	Allows time for DWR and USBR to establish monitoring stations.
Condition 6 waiver	9/9/88	Grants DWR exemption to meeting Suisun Marsh water quality standards for the dates of 11/1/88 through 5/31/89.	DWR testing the effectiveness of the SMSCG.
Condition 6 waiver	1/24/90	Grants DWR exemption to meeting Suisun Marsh water quality standards for the dates of 1/24/90 through 5/31/90.	Allows for second year of SMSCG effectiveness testing.
Condition 6 waiver	1/21/94	Grants DWR exemption to meeting water quality standards at stations S-21 and S-97 for the period of 2/1/94 through 5/31/94.	DWR testing effects of Green Valley Creek flow augmentation.
Resolution 94-90	9/22/94	Grants DWR Condition 6 waiver for meeting water quality standards at (1) stations S-49 and S-64 for 10/1/94 through 11/30/94, and (2) stations S-21, S-97, and S-75 for 10/1/94 through 5/31/95. Deficiency standards in effect from December through May at S-21, S-97, and S-75.	DWR testing effects of SMSCG operation on adult salmon upstream migration.
Water Quality Control Plan	5/95	Revised compliance dates for Suisun Marsh Standards	Establishes water quality control measures in the Bay-Delta Estuary
Order 95-6	6/95	Extended compliance dates of S-35 and S-97 to 10/1/97	Interim order to resolve conflicts between D-1485 and the 1995 WQCP.
Temporary Order	10/30/97	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/30/97 through 4/28/98.	Allows for completion of SMPA Amendment 3.
Temporary Order	8/14/98	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/1/98 through 3/29/99.	Allows for completion of SMPA Amendment 3.
Order 98-6	9/17/98	Grants DWR Condition 6 waiver for meeting water quality standards granted for stations C-2, S-64, S-49, S-42, and S-21 during 10/1/98 through 5/31/2001.	Continuation of SMSCG adult salmon migration test.
Order 98-9	12/98	Authorizes extension for final SEW report until 6/1/99. Waives water quality standards for SMSCG salmon test.	Extends provisions of WR Order 95-6.
Temporary Order	4/30/99	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 4/30/99 through 10/27/99.	Allows for completion of SMPA Amendment 3.
Temporary Order	11/1/99	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/27/99 through 4/24/00.	Allows for completion of SMPA Amendment 3.

5. Identify studies to be conducted that will help determine the types of actions necessary to protect the Suisun Bay area, including Suisun Marsh.

6. Perform studies to evaluate the effect of deep water channel dredging on Suisun Marsh channel water salinity.

7. Perform studies to evaluate the effects of urbanization in the Suisun Marsh on the Suisun Marsh ecosystem.

8. Develop a sliding scale between the normal and deficiency objectives for the western Suisun Marsh.

The Suisun Marsh Preservation Agreement Amendment Three and Suisun Ecological Workgroup are parallel processes that focus on different aspects of Suisun Marsh protection. The Suisun Marsh Preservation Agreement focuses on protection of managed wetlands, while the Suisun Ecological Workgroup is developing recommendations for the SWRCB for comprehensive water quality standards that will be protective of tidal marsh, aquatic, and managed marsh habitats.

1998 Water Rights Order WR 98-9

In December 1998, the SWRCB adopted Order WR 98-9 to extend the provisions of Order WR 95-6, with minor modifications, through 31 December 1999. The following changes were made regarding Suisun Marsh:

- Authorization of a time extension until 1 June 1999 for submittal of the final SEW report.

- Exceedances of objectives at Suisun Marsh compliance stations during the Suisun Marsh Salinity Control Gate salmon passage experiment will not be considered a violation of water right permit conditions. The experiment will be conducted from October 1998 through May 2001.

- Notes the SWRCB order allowing a temporary extension of the effective compliance dates at western Suisun Marsh compliance stations from 1 October 1998 to 1 April 1999 and the option for additional extensions.

Chapter 5
Permit Authorization

This chapter summarizes the relevant history of permit authorization for SMPA activities in the Suisun Marsh.

1979 San Francisco Bay Conservation and Development Commission Permit Number 35-78(M)

On 13 March 1979, BCDC issued Permit 35-78(M) to DWR for construction and operation of the Initial Facilities, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall (SFBCDC 1991b).

1979 US Army Corps of Engineers Permit Number 12572-58

On 12 April 1979, the USACE issued 404 Permit 12572-58 to DWR for construction and operation of the Initial Facilities (USACE 1979).

1981 USFWS Biological Opinion

On 7 December 1981, USFWS issued a Biological Opinion (1-1-81-F-130) to USBR for the Suisun Marsh Management Plan.

This Biological Opinion addressed adverse effects on salt marsh harvest mouse (*Reithrodontomys raviventris*) and California clapper rail (*Rallus longirostris obsoletus*) from the construction and operation of the facilities ultimately included in the Plan of Protection as well as the maintenance activities routinely conducted in the Suisun Marsh. The Biological Opinion evaluated four aspects of activities that would likely occur in the Suisun Marsh: (1) construction and operation of physical facilities; (2) monitoring programs; (3) management programs for the waterfowl hunting clubs in the Suisun Marsh; and (4) conservation measures.

In the “Project Impacts” section, the Biological Opinion stated that the project's construction and management activities, as well as implementation of the management plans, could have a significant effect on the salt marsh harvest mouse. However, the Biological Opinion also stated that the compensatory actions described in the Suisun Marsh Management Plan to offset such effects ensure the continued existence of the salt marsh harvest mouse in the Suisun Marsh. These compensatory actions are described **below**:

Retain and manage at least 1,000 acres of preferred salt marsh harvest mouse habitat and monitor salt marsh harvest mouse habitat marshwide every three years, with an ultimate goal of 2,500 acres adequately distributed throughout the Suisun Marsh. The 1,000 acres retained must meet certain criteria (in other words, 100% cover, 50% to 100% pickleweed cover, 40% of the Suisun Marsh usable in the winter with little or no flooding, 80% usable for salt marsh harvest mouse in the summer). Parcels established for this purpose would range in size from 100 to 500 acres. Monitoring of the salt marsh harvest mouse habitat is the responsibility of DFG and is to be coordinated with USFWS.

The Biological Opinion stated that out of a total of 378 acres of wetlands to be created as total compensation for all wetland habitat losses, at least 100 acres of habitat were to be created for the salt marsh harvest mouse, with management providing “for the specific habitat requirements” of the salt marsh harvest mouse.

Five zones were established in Suisun Marsh for aerial flyovers. If preferred salt marsh harvest mouse habitat acreage in any of these zones decreases by one-third, the club management plans would be modified to maintain tracts of salt marsh harvest mouse habitat throughout the Suisun Marsh. Aerial photography and ground truthing would be conducted at three-year intervals in order to monitor changes in preferred salt marsh harvest mouse habitat and determine the need to modify club management plans.

The Biological Opinion stipulates five terms and conditions, with the most notable being the fifth. This condition requires (1) systematic survey of salt marsh harvest mouse populations by monitoring control areas, management areas, and State areas managed for the salt marsh harvest mouse; (2) salt marsh harvest mouse trapping compatible with the habitat monitoring and aerial surveys; and, (3) coordination with the USFWS on the design of these studies and subsequent data review.

1984 San Francisco Bay Conservation and Development Commission Permit Number 4-84(M)

On 26 June 1984, BCDC issued Permit 4-84(M) for the construction and operation of the SMSCG (SFBCDC 1991a). Included in the permit was the requirement for DWR to monitor the effects of the project pursuant to a monitoring program prepared by DWR in consultation with DFG.

1985 BCDC Resolution 85-9

The BCDC certified the existing Individual Ownership Management Plans in Resolution 85-9 under BCDC's certified local protection program. Also, Section 29508 of the Public Resources Code, a section of the SMPA, specifically exempts certain activities in the Suisun Marsh from the need to obtain a marsh development permit from BCDC. When the Individual Ownership Management Plans are updated, as described in this Amendment Three, BCDC would need to recertify them according to provisions of the Suisun Marsh Local Protection Program.

1986 USFWS Biological Opinion

On 14 March 1986, USFWS issued a Biological Opinion (1-1-86-F-27) in response to a USACE request for formal consultation on the construction of the SMSCG and associated levee maintenance and dredge spoil disposal. The opinion addressed the adverse effects on the salt marsh harvest mouse from the proposed project. This opinion referenced the 1981 Biological Opinion with regard to effects on the salt marsh harvest mouse and California clapper rail, and stated that, “…the project, as proposed at that time, remains substantially unchanged. However, USACE authorization, plus the proposed addition of the two dredge spoil disposal sites on Van Sickle Island, introduces new effects on salt marsh harvest mouse that warrant formal consultation.”

In the “Effects of the Proposed Project” section, USFWS stated that the construction and operation of the SMSCG will, in large part; determine future habitat conditions available to salt marsh harvest mouse over thousands of acres throughout the Suisun Marsh. Thus, all agreements relating to salt marsh harvest mouse protection should be fulfilled or in the process of being fulfilled before USFWS endorses the project.

1986 US Army Corps of Engineers Permit Number 16223E58

On 7 May 1986, the USACE issued 404 Permit 16223E58 to DWR for construction and operation of the SMSCG (USACE 1986). The permit states that the permittee shall perform the reasonable and prudent measures and conservation recommendations as outlined and contained within the 1986 Biological Opinion. Thus, all the Conservation Recommendations in the 1986 Biological Opinion for the SMSCG became binding conditions of USACE authorizations.

1993 National Marine Fisheries Service Biological Opinion

The National Marine Fisheries Service (NMFS) addressed operation of SMSCG in the 12 February 1993, Biological Opinion on the operation of the CVP and the SWP. Included in the NMFS Biological Opinion was the potential for the reinitiating of consultation to reevaluate effects of the SMSCG on fisheries resources.

US Fish and Wildlife Service Letter Dated 2 May 1994

In a letter dated 2 May 1994, the USFWS further clarifies recommendations and maintenance restrictions regarding California clapper rails in the Suisun Marsh. The letter states that no adverse effect to the California clapper rail would occur provided that all maintenance activities avoided the California clapper rail breeding season (1 February through 31 August) in locations where California clapper rails were known to occur. This letter specifies four areas, approximately 87,350 linear feet of levee, within the Suisun Marsh of known California clapper rail nesting or breeding locations. The letter also states that breeding season restrictions can be relaxed if surveys completed by a competent biologist in the year that work is anticipated indicate that no California clapper rail nesting territories are within 500 feet of these levees.

1994 US Fish and Wildlife Service Biological Opinion

On 29 August 1994, USFWS issued a Biological Opinion (1-1-94-F-20) to the San Francisco District Office of USACE, which addressed the effect on delta smelt (*Hypomesus transpacificus*) and proposed Sacramento splittail (*Pogonichthys macrolepidotus*) due to SRCD's and DFG's periodic maintenance activities within Suisun Marsh. The Biological Opinion states that the effects of the project on salt marsh harvest mouse were addressed in USFWS’ 14 March 1986 Biological Opinion. It further states that the effects on the California clapper rail were addressed in USFWS’ letter dated 2 May 1994 to USACE (1-1-94-I-841).

1994 National Marine Fisheries Service Biological Opinion

On 21 September 1994, NMFS issued a Biological Opinion (reference 1-1-94-I-841), to assess the effects on the endangered Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*) of the SRCD’s and DFG’s proposal to perform periodic maintenance activities within Suisun Marsh.

National Marine Fisheries Service Letter Dated 24 November 1997

A letter dated 24 November 1997 gave concurrence to proceed with Amendment Three under informal consultation. The parties have incorporated the changes to the proposed amendment to the SMPA recommended in the letter by NMFS.

1998 DFG Draft Biological Opinion

In May 1998, DFG issued a draft Biological Opinion, which assessed the impact of implementing Amendment Three on listed and non-listed species in the Suisun Marsh. DFG's finding after reviewing the project was that Amendment Three will not have incremental impacts above those of the Original Agreement. The Biological Opinion stated that the Original Agreement and the associated mitigation and permits provide adequate protection to listed and nonlisted species within the Project area. The Biological Opinion found that Amendment Three would not jeopardize the continued existence of any State listed species.

Pursuant to Fish and Game Code Section 2091, DFG identified Reasonable and Prudent Measures (RPMs) as necessary and appropriate to minimize the adverse impacts of incidental takes. These RPMs, which are listed below, were incorporated by DFG into the 1998 Draft Biological Opinion. Any taking that is in compliance with these measures and the measures prescribed in the federal Biological Opinion would not be prohibited by the California Endangered Species Act. The RPMs are:

- All conditions and requirements of SRCD's original Regional General Permit No. R20066E98 for maintenance activities in Suisun Marsh, and its associated biological opinions shall be implemented.

- The last installment of the mitigation funds associated with the Original Agreement shall be used for multi-species management.

- A multi-agency Environmental Coordination Advisory Team shall be established to ensure compliance with required mitigation obligations.

Other Miscellaneous Permits

Other miscellaneous permits obtained for activities in the Suisun Marsh include BCDC permits for installation of water quality monitoring stations, as well as DFG 1601 streambed alteration agreements and RWQCB 401 water quality waivers as applicable.

Chapter 6
Physical Facilities

Several facilities have been constructed by DWR and USBR and operate in the Suisun Marsh. These facilities (see Figure 17) are identified in the Plan of Protection for the Suisun Marsh and the 1987 SMPA. The purpose of these facilities is to provide lower salinity water to managed wetlands. The Initial Facilities, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall, were constructed in 1979 and 1980. The SMSCG were installed and became operational in 1988. Other facilities constructed under the SMPA include the Cygnus Drain and the Lower Joice Island Diversion. The existing facilities are described in detail in this chapter. Several additional large-scale facilities are identified in the Plan of Protection for the Suisun Marsh and the original SMPA, and were to be phased in for salinity control in the Suisun Marsh. However, due to the effectiveness of the Initial Facilities and the SMSCG, and increased outflows, there are no plans to construct additional facilities.

Roaring River Distribution System

The Roaring River Distribution System was constructed in 1979 and 1980 to provide wetland managers on Simmons, Hammond, Van Sickle, and Wheeler islands with lower salinity water. Construction involved enlarging Roaring River and extending its western end. Excavated material was used to widen and strengthen the levees on both sides of the system. A bank of eight 60-inch culverts brings lower salinity water into the system from Montezuma Slough. The culverts are equipped with a fish screen at the intake to minimize diversion of fish into Roaring River Slough. To provide an adequate water supply during fall flood-up, a pond was constructed near the confluence with Montezuma Slough to increase the capacity of the system. This system provides water for approximately 5,000 acres of managed wetlands.

Morrow Island Distribution System

The Morrow Island Distribution System, in the western Suisun Marsh, was also constructed in 1979 and 1980. The system is composed of two channels known as M-line and C-line. The channels divert water from Goodyear Slough to the easternmost area of Morrow Island. The purpose of the system is to allow wetland managers to fill their ponds with lower salinity water from Goodyear Slough or the Morrow Island Distribution System and drain into Grizzly Bay or Suisun Slough. This reduces the introduction of high-salinity drainage water into Goodyear Slough.

Goodyear Slough Outfall

The Goodyear Slough Outfall was constructed to connect the south end of Goodyear Slough to Suisun Bay. Prior to construction of the Outfall, Goodyear Slough was a dead-end run. The system was designed to increase circulation and reduce salinity in Goodyear Slough and to provide lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water.

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates (SMSCG) were completed and began operating in October 1988. The first year of operation was used to test the gates, and official operation began in November 1989. The facility consists of a boat lock, a series of three radial gates, and flashboards. The SMSCG control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the SMSCG in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west. When Delta outflow is low to moderate and the SMSCG are not operating, net movement of water is from west to east, resulting in higher salinity water in Montezuma Slough.

The SMSCG usually begin operating in early October and, depending on salinity conditions, may continue operating through the end of the control season in May. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the SMSCG raised to allow unrestricted movement through Montezuma Slough. Details of annual SMSCG operations can be found in *Summary of Salinity Conditions in Suisun Marsh During Water Years 1984–1992* (DWR 1994b), or the *Suisun Marsh Monitoring Program Data Summary* produced annually by DWR's Environmental Services Office.

Lower Joice Island Unit

The Lower Joice Island Unit consists of two 36-inch diameter intake culverts on Montezuma Slough near Hunter Cut and two 36-inch diameter culverts on Suisun Slough, also near Hunter Cut. Both sets of culverts were called for in the original SMPA and installed in the existing levee in 1991. The facilities include combination gates on the slough side and flap gates on the landward side. The Lower Joice Island facility allows more rapid filling of the site and is connected to the existing distribution system on Individual Ownership Number 424. This facility enables the individual ownership to properly manage its wetlands on Lower Joice Island. Construction of the Lower Joice Island Facility was authorized under SRCD's regional general permit. Under the original SMPA, DWR was responsible for constructing the Lower Joice Island Unit and the individual ownership had the responsibility for operation and maintenance.

Cygnus Unit

The Cygnus Unit includes the installation of a 36-inch drain gate with flashboard riser on Individual Ownership Number 415. Installation of this drain gate was authorized under SRCD's regional general permit and installed in 1991. The individual landowner is responsible for operation and maintenance of this gate.

Cost-Share Facilities

In addition to the facilities mentioned previously, numerous small facilities exist in the Suisun Marsh, many of which were installed or replaced under the DWR and USBR individual cost-share program. The individual ownership cost-share program, as specified in the SMPA, is a program to improve the landowners ability to drain managed wetlands. Under this program, DWR and USBR reimburse 75% the landowners of the cost of replacing culverts (enlarging or lowering) and drain gates, and installing pumps. The individual landowners are responsible for the remaining 25%. The proposed facilities must be specified as "Needed Improvements" in the Individual Ownership Management Plans before being approved for inclusion in this program.

Chapter 7

Suisun Marsh Monitoring and Reporting Requirements

Requirements of the Suisun Marsh Monitoring Agreement

The Monitoring Agreement required the following monitoring using specific methodologies described in Appendix B of the Plan of Protection:

- **Channel Water Electrical Conductivity.** The electrical conductivity at the Control Stations will be monitored by DWR with continuous recorders…
- **Diversion and Drain Water Electrical Conductivity.** A point on each Monitored Ownership shall be monitored continuously for electrical conductivity by DWR.
- **Pond Water.** The electrical conductivity of standing surface water at each soil water salinity site…shall be determined monthly by DWR.
- **Pond Stage.** DWR shall maintain a continuous recorder to measure water elevation on each of the Monitored Ownerships. At each of the control stations, DWR shall maintain a continuous recorder to measure water elevation for five years.
- **Soil Water Salinity.** Soil water salinity will be monitored by DWR at 40 to 50 sites on Monitored Ownerships and one site on Individual Ownership 423.
- **Vegetation Occurrence.** The specific composition of vegetation on lands within 35 meters of each soil water monitoring site will be determined by DFG in August or September of each year. The percent of cover contributed by each plant species present on the sample site will be determined by DFG each year.
- **Vegetation Production.** The seed production of alkali bulrush and fat hen present on lands within 35 meters of each soil water monitoring site will be determined by DFG each year.
- **Triennial (Marshwide) Vegetation Survey.** The overall vegetative composition of the Suisun Marsh shall be determined by DFG every third year…using aerial photography…These aerial photos will also be used to determine any net acreage changes in preferred salt marsh harvest mouse habitat…
- **Salt Marsh Harvest Mouse Surveys.** If the marshwide plant survey indicates a significant change…in preferred habitat…then the parties shall determine whether any surveys of the population of the mouse are necessary. If…necessary, DWR will promptly arrange for such surveys to be made.
- **Waterfowl Survey.** Species and number of waterfowl in the Suisun Marsh will be determined from aerial surveys carried out by DFG from September through January of each year…

- **Young Striped Bass and *Neomysis*.** DWR or DFG will arrange for or conduct studies of the annual abundance of young striped bass and *Neomysis* in Montezuma Slough.

- **Effects of SMSCG on Fish.** DWR or DFG will arrange for or conduct studies to determine the impact of predators and disruption of fish associated with the SMSCG.

Monitoring Requirements of Other Permits

USACE Permit 16223E58C for Construction of the Suisun Marsh Salinity Control Gates

- Determine the effects of the SMSCG on the aquatic environment.

- Establish the magnitude and nature of delays and predation losses to migratory fish and other indicator species.

- Determine whether salt marsh harvest mouse habitat on the Van Sickle Island has reestablished, by conducting botanical surveys of the dredge spoil sites for three growing seasons after spoil removal to document plant succession and reestablishment.

BCDC Permit 4-84(M) for Construction of the Suisun Marsh Salinity Control Gates

- Measurements of existing water quality, fish and wildlife resources, and wetland habitat in the Suisun Marsh that may be affected by the project.

- Measurement of water quality throughout the Suisun Marsh during operation of the facilities.

- A continuing study of fishery resources and related aquatic life that may be impacted by the project.

- A continuing study of the composition, diversity, and density of plant and wildlife populations within the areas of the Suisun Marsh affected by the project.

BCDC Permit 35-78(M) for Construction of the Initial Facilities

- A comparison of water and soil salinities within the areas served by the Initial Facilities to the salinities with neighboring areas not served by the facilities, and to measurements taken in years preceding the construction of the facilities.

- An assessment of any significant changes in the composition, diversity, or density of plant and wildlife populations in any area affected by operation of the facilities.

Table 6 Contract and regulatory reporting requirements provided in annual reports

Information Included	*Data Summary Report*	*SMSCG Fisheries Report*	*Permit or Contract Requiring Information* [a]
Monthly Mean High Tide Salinity	x		SWRCB, SMMA
Salt Marsh Harvest Mouse Surveys	x		USFWS BO
Triennial Vegetation Surveys [b]	x		SMMA
Waterfowl Population Surveys	x		SMMA
Routine Maintenance Performed	x		BCDC
Maintenance Scheduled for Next Year	x		BCDC
UC Davis Fish Sampling		x	SWRCB [c], SMMA, USACE, BCDC
Striped Bass Tow-Net Survey		x	SMMA, USACE, BCDC
Phytoplankton and *Neomysis* Surveys		x	SMMA, BCDC, USACE
Striped Bass Egg and Larva Survey		x	SMMA, USACE, BCDC
Juvenile Chinook Salmon Monitoring		x	SMMA, USACE, BCDC, NMFS
Predator Sampling		x	SMMA, USACE, BCDC, NMFS
Adult Salmon Migration Study		x	SMMA, USACE, BCDC, NMFS
Water Quality Profiling Program		x	SWRCB [c]

[a] SMMA: Suisun Marsh Monitoring Agreement
USACE: US Army Corps of Engineers Permit 16223E58
BCDC: San Francisco Bay Conservation and Development Commission Permits 35-78(M) and 4-84(M)
USFWS BO: US Fish and Wildlife Service Biological Opinion 1-1-81-F-131
SWRCB: State Water Resources Control Board D-1641
NMFS: National Marine Fisheries Service February 12, 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project

[b] Survey conducted and results reported every three years.

[c] Initiated under D-1485, requirement to conduct special studies to develop a better understanding of the hydrodynamics, water quality, productivity, and significant ecological interactions of the Suisun Marsh. This requirement remains unchanged in D-1641.

Annual Reporting Requirements

The Suisun Marsh Monitoring Agreement; San Francisco Bay Conservation and Development Commission permits 4-84(M) for construction of the Suisun Marsh Salinity Control Gates and 35-78(M) for construction of the Roaring River Distribution System; and US Army Corps of Engineers Permit 16223E58 for construction of the Suisun Marsh Salinity Control Gates all require an annual report detailing the results of environmental monitoring required by the individual permits (BCDC 1991a, 1991b; USACE 1986). These annual reporting requirements have been consolidated into two annual reports: Suisun Marsh Monitoring Program Data Summary, and Suisun Marsh Salinity Control Gates Fisheries Monitoring. Table 6 summarizes the monitoring information included and regulatory or contract requirement fulfilled in each of the two reports. In addition, the State Water Resources Control Board requires an annual report summarizing compliance with Suisun Marsh water quality standards and progress toward implementation of mitigation facilities. This annual report provides a progress and status report on all Suisun Marsh activities conducted by DWR and USBR.

Chapter 8
Suisun Marsh Monitoring Program

Channel Water

Data on salinity and tide stage are collected from a network of sites in Suisun Marsh channels. Table 7 lists all the channel water salinity and tide stage stations with their active dates. Figure 18 shows the current network of tide and salinity monitoring stations in channels though the Marsh. Currently, there are five SWRCB compliance stations (C-2, S-64, S-49, S-42, and S-21) and two SWRCB baseline monitoring stations (S-35 and S-97) in the marsh that collect specific conductance data as mandated by D1641. Data from the Mallard monitoring station are indicative of the third SWRCB baseline monitoring “station” for water supply intakes on Chipps and Van Sickle islands. Tide stage and specific conductance data are continuously monitored at 15-minute intervals and data are telemetered to the California Data Exchange Center in Sacramento.

Individual Ownership Monitoring

Data collection on the monitored ownerships began in October 1984, at the beginning of the 1985 water year. Forty-five sites were established on eleven ownerships across the Suisun Marsh. A pond stage recorder was installed on each ownership except Family Club, and stations to measure the specific conductance of drain water were placed on seven ownerships (see Figure 18, Table 8). Most sites had three soil tubes installed to collect water at a depth of six inches below the soil surface. Four sites had one tube each at depths of three, six, and nine inches, which were used to determine whether the six-inch tubes collected a representative sample of the water in the top 12 inches of soil. The first foot of soil was chosen as the area of interest because most water management in the Suisun Marsh was tailored to favor the growth of alkali bulrush (*Scirpus maritimus*), and its roots do not grow much deeper than one foot.

In November 1985, two ownerships (two sites on West Family and one on Goodyear Slough Unit) and an additional site on Grizzly Island (49) were added to the program. These four sites were managed for fat hen (*Atriplex triangularus*) rather than alkali bulrush. Because fat hen's roots grow deeper than those of alkali bulrush, three soil tubes were set to collect soil water at each of three depths, 6, 18, and 30 inches. These sites did not have pond stage recorders installed until water year 1991 (West Family) or 1992 (Grizzly Island and Goodyear Slough Unit).

The Suisun Marsh Monitoring Agreement states that “monitoring on Individual Ownerships shall terminate on 30 September 1990 unless the parties mutually agree otherwise.” In 1990, it was decided that further data collection was needed to help confirm the relationships between surface water salinity and soil water salinity, and the program continued with some adjustments. Two pond stage recorders were added (PSR 92 at Tule Belle, and 93 at West Family), one was removed (78 at Joice Island), and 11 soil tube sites were dropped because access was difficult, the site was rarely flooded, or data collected at the site was duplicated at another site on the same ownership.

At the beginning of water year 1992, nineteen sites were dropped from the monitoring program, leaving 19 sites on nine ownerships. In water year 1993, 12 sites were dropped, and two sites on a “new” ownership (Sunrise Farms) were added, for a total of nine sites on six ownerships. These sites were monitored for the next three years, until all on-site monitoring ended in September 1995. Information for the on-site monitoring, including active dates of the soil tube sites and pond stage recorders, are listed in Table 8.

Table 7 Channel water salinity and tide stage monitoring sites in Suisun Marsh, 1980–2000

		Active Dates		
Site Number	*Site Name*	*From*	*To*	*Dates as Compliance*
	Chipps Island @ O&A Ferry Landing	1/20/83	6/1/95	10/84 – 6/95 [a]
C-2 ■	Collinsville	5/13/85 [b]	Present	10/84 – Present
S04	Hill Slough @ Grizzly Road	01/26/82	Present	N/A
S10	Green Valley Creek @ Green Valley Road	10/04/94	Present	N/A
S15	Suisun Creek @ Cordelia Road	03/01/91	01/06/97	N/A
S16	Suisun Creek @ Cordelia Road	6/26/98	Present	N/A
S20	Chadbourne Slough @ Hollywood Club	04/14/94	07/01/97	N/A
S21 ■	Chadbourne Slough @ Sunrise Club	02/89	Present	10/93 – Present
S28	Teal Club	10/15/81	Present	N/A
S33	Cordelia Slough @ Cygnus	01/20/83	Present	N/A
S34	Cordelia Slough @ Miramonte	08/94	06/24/97	N/A
S35 ♦	Goodyear Slough @ Morrow Island	03/15/83	Present	N/A [c]
S37	Suisun Slough @ Godfather II	5/15/92 [d]	Present	N/A
S40	Boynton Slough @ Bullsprigs Club	02/28/92	Present	N/A
S42 ●	Suisun Slough @ Volanti Slough	01/20/83	Present	10/84 – Present
S49 ■	Montezuma Slough @ Beldons	01/13/83	Present	10/84 – Present
S54	Montezuma Slough @ Hunter Cut	12/07/82	Present	N/A
S64 ■	Montezuma Slough @ National Steel	01/21/83	Present	10/84 – Present
S71	Montezuma Slough @ Roaring River	07/15/85	Present	N/A
S72	Roaring River @ Montezuma Slough	07/23/85	Present	N/A

Legend: ■ SWRCB Compliance monitoring station, ♦ SWRCB Baseline monitoring station, ● SWRCB Compliance and baseline monitoring station

[a] Water quality standard at this station removed in 1995 SWRCB Water Quality Control Plan and SWRCB WR 95-6.

[b] Not Active From 2/87 To 10/17/88.

[c] Compliance was never implemented. Requirement to meet standards removed in D-1641.

[d] Not active from 6/10/92 to 8/25/93 and 10/13/93 to 1/16/94.

[e] DWR received SWRCB waivers and extensions for meeting standards from February 1, 1994 through December 31, 1999. Requirement to meet standards removed in D-1641.

[f] This station was never established. Under the D-1485 Amendment the standards were to become effective 10/1/97. In the 1995 SWRCB Water Quality Control Plan there were no dates for the standard. In D-1641 the station was converted from a compliance to a monitoring station.

Table 7 Channel water salinity and tide stage monitoring sites in Suisun Marsh, 1980–2000

		Active Dates		
Site Number	*Site Name*	*From*	*To*	*Dates as Compliance*
S90	Roaring River @ Sprig	10/15/82	Present	N/A
S97 ♦	Cordelia Slough @ Ibis	12/90	Present	10/93 – 1/94 [e]
S98	Cordelia Slough @ Garibaldi	04/94	05/02/97	N/A
A47	Suisun Slough @ Mouth	02/16/83	07/15/87	N/A
A52	Morrow Island Club Drain	10/15/81	06/13/94	N/A
A53	Tule Belle Club Drain	01/20/82	05/06/91	N/A
A54	Cordelia Slough @ Golden Gate	02/04/81	06/08/83	N/A
A58	Gum Tree at Club (North) Drain	10/15/81	07/90	N/A
A59	Joice Island Drain	12/30/82	07/90	N/A
A60	Mallard Farms Drain	10/16/81	07/06/92	N/A
A61	Grizzly King Drain	10/15/81	04/88	N/A
A62	St. Germain Intake	06/03/82	07/11/90	N/A
A63	F&G Grizzly Drain (Parking Lot 8)	01/03/83	07/03/91	N/A
A65	Roaring River Intake	10/16/81	06/04/85	N/A
A66	F&G Grizzly Intake	12/28/82	12/10/90	N/A
A68	Grizzly King Club	12/16/82	07/13/92	N/A
A69	Gum Tree Intake (South)	10/15/82	11/01/91	N/A
A70	Joice Island Intake	10/01/82	05/15/91	N/A
A96	Goodyear Slough @ Fleet	09/16/82	Present	N/A
--- ♦	Water supply intakes for waterfowl management areas on Van Sickle Island and Chipps Island	Not implemented		N/A[f]

Legend: ■ SWRCB Compliance monitoring station, ♦ SWRCB Baseline monitoring station, • SWRCB Compliance and baseline monitoring station

[a] Water quality standard at this station removed in 1995 SWRCB Water Quality Control Plan and SWRCB WR 95-6.

[b] Not Active From 2/87 To 10/17/88.

[c] Compliance was never implemented. Requirement to meet standards removed in D-1641.

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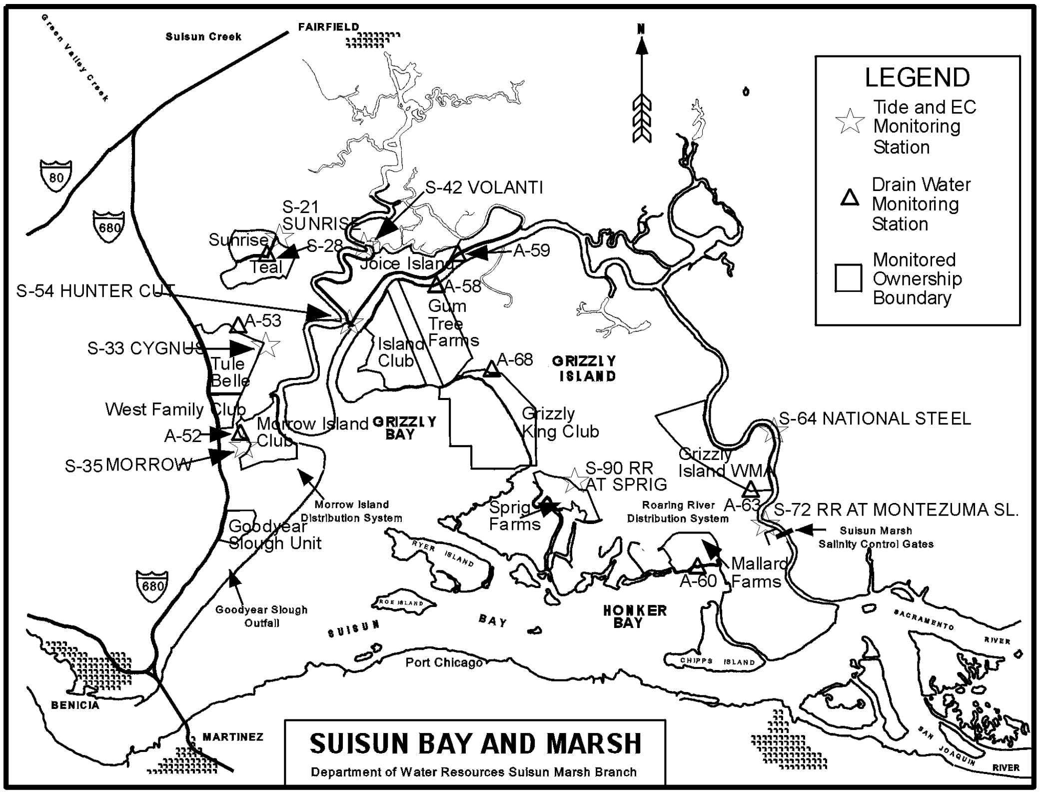

Figure 18 Monitored ownerships and channel and drain water monitoring stations from the DWR Suisun Marsh Monitoring Program

Table 8 Soil tube sites and pond stage recorders in Suisun Marsh from 1982 to 1995

Club	*Soil Tube Site #*	*Active Dates*	*Pond Stage Recorder*	*Active Dates*	*Drain Water EC Station*	*Active Dates*	*Channel Water EC Station*	*Soil Type*
Morrow Island	1	8/84 - 9/92	97	10/91 - 10/92	A52	10/81 - 6/94	S-35	Reyes
	2	8/84 - 9/92	75	9/83 - 10/92				Reyes
	3	8/84 - 10/90						Reyes
	4	8/84 - 9/92						Tamba
Family	5	8/84 - 10/90					S-35	Tamba
Tule Belle	6	8/84 - 11/91			A53	11/82 - 5/91	S-33	Tamba
	7	8/84 - 9/95	92	9/90 - 9/95				Joice
	8	8/84 - 11/91						Reyes
	9	8/84 - 11/91	76	10/82 - 9/92				Tamba
	10	8/84 - 10/90						Reyes
Teal	11	8/84 - 10/90			S28		S-21	Tamba
	11.1	10/91 - 9/92	95	8/91 - 10/92				
	12	8/84 - 9/92						Tamba
	13	8/84 - 10/90						Reyes
	13.1	9/91 - 9/92	77	9/91 - 10/92				

Table 8 Soil tube sites and pond stage recorders in Suisun Marsh from 1982 to 1995 (Continued)

Club	*Soil Tube Site #*	*Active Dates*	*Pond Stage Recorder*	*Active Dates*	*Drain Water EC Station*	*Active Dates*	*Channel Water EC Station*	*Soil Type*
	14	8/84 - 9/92	77	12/82 - 10/92				Joice
Joice Island	15	8/84 - 10/91					S-42	Tamba
	16	9/84 - 11/91			A59	12/82 - 7/90		Tamba
	17	8/84 - 11/91						Tamba
	18	8/84 - 10/91	78	10/82 - 11/90				Reyes
Island Club	19	8/84 - 11/91			None		S-54	Tamba
	19.1	9/92 - 9/95						
	20	8/84 - 5/93	80	10/82 - 9/95				Tamba
	21	8/84 - 11/91						Joice
	22	8/84 - 11/91						Joice
Gum Tree	23	8/84 - 11/91			A58	10/81 - 7/90	S-54	Joice
	24	8/84 - 11/91					A-69	Joice
	25	8/84 - 11/91						Tamba
	26	8/84 - 11/91	79	10/82 - 9/92				Tamba
Grizzly King	27	8/84 - 10/91			A-61	10/81 - 4/88	A-68	Valdez
	28	8/84 - 9/92	82	10/82 - 9/92				Valdez
	29	8/84 - 10/90						Valdez
	30	8/84 - 9/92						Valdez
Sprig	31	8/84 - 11/91			None		S-90	Tamba
	32	8/84 - 11/91						Tamba
	33	8/84 - 11/91						Valdez
	34	8/84 - 11/91	83	10/82 - 7/92				Joice
	35	8/84 - 11/91	83	10/82 - 7/92				Joice
Grizzly Island	36	8/84 - 10/90			A63	1/83 - 7/91	S-64	Valdez
	37	8/84 - 11/91	87	10/87 - 10/92				Suisun
	38	8/84 - 10/90	85	10/82 - 7/89				Suisun
	39	8/84 - 10/90						Reyes
	40	8/84 - 11/91	88	10/89 - 10/92				Tamba
	49	11/85 - 9/95	96	9/91 - 9/95				Tamba
Mallard Farms	41	8/84 - 10/90	84	10/82 - 8/89	A60	10/81 - 7/92	S-72	Valdez
	42	8/84 - 9/92					S-90	Suisun
	43	8/84 - 9/92	84A	8/89 - 10/92			in 1987	Joice
	44	8/84 - 11/91						Tamba
	45	8/84 - 9/92						Tamba
West Family	46	11/85 - 9/95			None		S-35	Reyes
	47	11/85 - 9/95	93	8/90 - 9/95				Reyes
Goodyear	48	11/85 - 9/95	94	8/91 - 9/95	None		S-35	Reyes
Sunrise	50	10/92 - 9/95	98	12/92 - 9/95	None		S-21	Tamba
	51	10/92 - 9/95						Tamba

Vegetation Monitoring

Conservation measures outlined in the 1981 Biological Opinion required that vegetation monitoring be conducted in the Suisun Marsh. A monitoring plan was developed to assess the overall vegetative composition of the Suisun Marsh using color aerial photography in conjunction with ground verification every third year. The results would be compared to the results from past flights and reported in acres and percent of total vegetation for each major plant species. These surveys were completed in 1981, 1988, 1991, and 1994.

In addition to monitoring vegetation change across the Suisun Marsh, the Triennial Survey was supposed to monitor the acreage of preferred salt marsh harvest mouse habitat. To assist in this, the Suisun Marsh was divided into five zones to decrease the potential for significant local decreases in habitat being masked by increases in other areas of the Suisun Marsh. These zones, as shown in Figure 19, were established before the 1981 survey, and were used to analyze vegetation changes in each subsequent survey.

Although the aerial surveys were completed, the aerial photo interpretation and annual vegetation monitoring were not implemented. The five zones established in the Suisun Marsh have not been used for their original purpose of assessing changes in preferred salt marsh harvest mouse habitat. There were some concerns about the methodology used and the lack of useful maps from the 1988, 1991, and 1994 surveys. Determination of individual species composition marshwide would require an extremely intensive sampling effort with rigorous replication to report data at the species level with any degree of certainty. On the ground, marsh habitats are mixed assemblages of several species rather than monotypic stands. To lump percentages of species within each habitat into single species categories loses the character of the actual habitat.

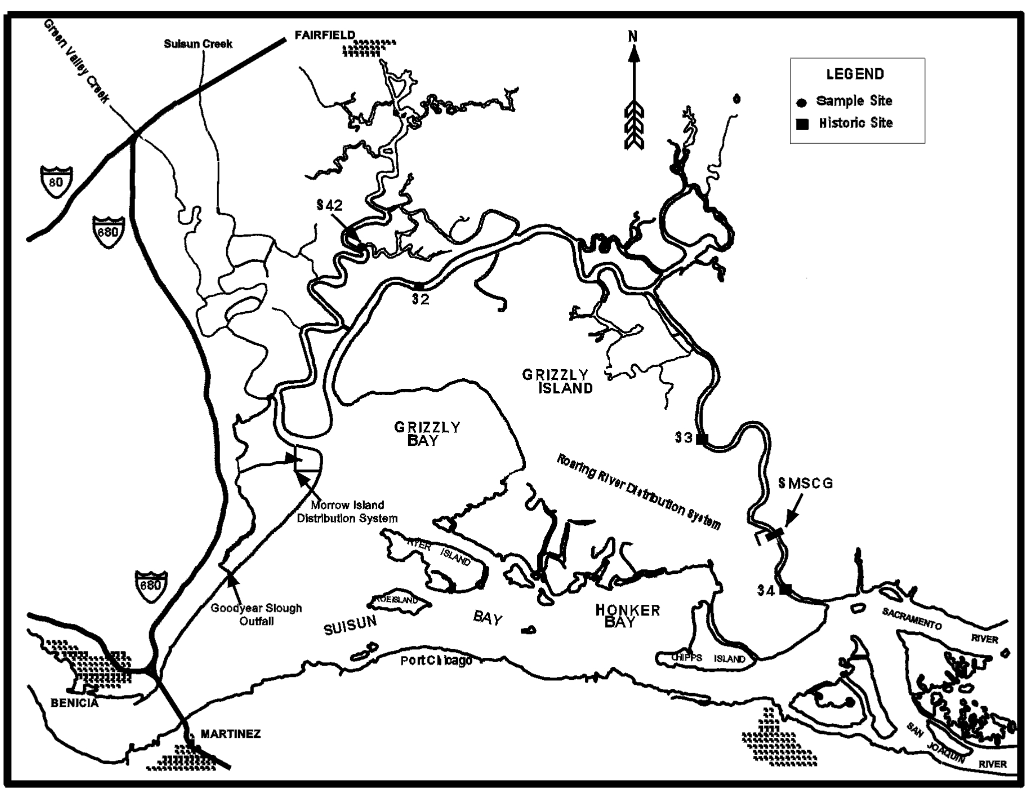

Figure 19 Sampling sites for the *Neomysis*, zooplankton, and chlorophyll *a* survey in Montezuma Slough

The triennial vegetation survey scheduled for water year 1997 was postponed in order to update the objectives and methodology. In 1998, aerial photos were taken for use in a pilot study to develop an new survey methodology. A vegetation survey is to be conducted in 1999 under the direction of Dr. Todd Keeler-Wolf at DFG. The proposed survey methodology is designed to meet the goal of documenting changes in preferred habitat for the salt marsh harvest mouse, as well as gather the vegetation information in such a way that it can be used for a variety of other purposes, including correlating management activities with vegetation changes, gathering data to support the use of a GIS format that will allow queries, and overlaying of additional information (such as soil type and hydrology), and a creating a base map for future studies.

The vegetation mapping methodology to be used reflect the protocol for “Field Methods for Vegetation Mapping” supported by the National Park Service and Biological Resources Division of the US Geological Survey (USGS 1997). The value of this approach is a precise vegetation map with detailed classifications of vegetation. The specific methods of this monitoring plan are described in The Triennial Survey for the Suisun Marsh Proposal for a New Methodology (DFG 1999).

Salt Marsh Harvest Mouse Monitoring

In May 1998, the Suisun Marsh Preservation Agreement **ECAT** approved a DFG survey protocol for the salt marsh harvest mouse in the Suisun Marsh. The protocol has four objectives: (1) to monitor salt marsh harvest mouse population and habitat variability over time; (2) to determine whether the salt marsh harvest mouse is present on the 1,000 acres of mitigation land; (3) to evaluate habitat use to get a better idea of the habitat mosaic (pickleweed, upland refugia, and so on) that the salt marsh harvest mouse requires; and (4) to use the information gathered to guide management practices to maintain and/or develop salt marsh harvest mouse habitat.

Monitoring to address objective 2 (described previously) began in August 1998. One hundred live-traps were set in areas of best available habitat at each of the seven set-aside areas for three consecutive nights. In addition to surveying for the salt marsh harvest mouse, the vegetation in each trapping grid was surveyed. All species along randomly placed five-meter transects were recorded. This salt marsh harvest mouse presence and absence trapping will continue for two more years and will probably occur only every third year after that.

Once presence has been established, future trapping will be tailored toward monitoring and research needs, such as determining what areas are used as refugia, if and when the salt marsh harvest mouse uses suboptimal habitats, population dynamics in relation to flood levels, competition and interactions with other rodent species, and which areas of the Suisun Marsh support self-sustaining populations.

Using mark-recapture protocol will determine population sizes in different habitat types and in the different set-aside areas. This extended sampling is expected to begin in 1999.

Aquatic Resources Monitoring

Before installation of the SMSCG, DWR and USBR were required by the USACE permit to conduct a pre-project fishery resource evaluation to provide baseline information on the fish in Montezuma Slough (Spaar 1988). This information also allowed researchers to develop a monitoring plan for the Suisun Marsh. There are five topics addressed in the aquatic resources monitoring plan[7]. The goal of the monitor-

7. The aquatic resources monitoring plan was submitted to the regulatory agencies in Spaar 1988.

ing plan was to determine effects of SMSCG operation or the structure on *Neomysis*, general fish abundance, striped bass eggs and larvae, juvenile striped bass, chinook salmon. It is not possible to directly assess the impact of SMSCG on these resources, since the "control" or "background" condition for such an assessment (in other words, no gates) no longer exists. Thus, in general, the data analyses attempt to address the question indirectly by comparing data collected prior to SMSCG installation with that collected after the SMSCG were installed in 1988.

The purpose of the *Neomysis* monitoring is to determine if SMSCG operation affects the abundance of *Neomysis mercedis* and concentration of chlorophyll *a* over time. Chlorophyll *a* is an indicator of phytoplankton abundance and phytoplankton is the primary food source for zooplankton (Orsi 1995). *Neomysis mercedis* feed on smaller zooplankton and secondarily on phytoplankton (Obrebski and others 1992). *Neomysis mercedis* is an important dietary component for many Suisun Marsh fishes, including juvenile chinook salmon and striped bass (Wang 1986; Obrebski and others 1992).

The objectives of the general fish abundance study follow:

- Record long-term changes in fish populations due to environmental fluctuations and species introductions and add to the growing database on the Sacramento-San Joaquin Estuary.
- Monitor distribution and abundance of seasonal species of the Suisun Marsh, especially delta smelt, longfin smelt, chinook salmon and splittail.
- Track the movement of exotic species such as the shimofuri goby and the Asian clam.
- Track trends in diversity and abundance and determined habitat requirements of Suisun Marsh fishes and report the information annually.

The objective of the egg and larval survey is to provide an abundance index of developing striped bass through the spawning season. The tow-net survey provides an index of young-of-the-year striped bass abundance. The striped bass tow-net index estimates the abundance of young striped bass when the average length of the fish is 38.1 mm (1.5 inch). The 38.1-mm size was selected because the tow-net is most efficient for fish of that length.

When construction of the SMSCG was proposed, regulatory agencies raised concerns that the structure would increase predation losses to migrating juvenile fishes, such as chinook salmon, striped bass, and American shad. Regulatory agencies also raised concerns about delays to migrating species. To address the concerns, DWR proposed four studies:

- Sampling to estimate the losses of salmon associated with the SMSCG.
- Sampling to estimate use of Montezuma slough as a migration corridor to determine the significance of any loss.
- Sampling to determine if predator abundance increased near the SMSCG.
- Sampling to determine if gate operation delays the migration of adult salmon.

Chapter 9
Suisun Marsh Sampling Methodology

This section includes a discussion of the methodology, quality assurance and quality control, sample representativeness, and data limitations for the various parameters measured in the Suisun Marsh.

Channel Water

Method Evaluation

Tide stage and specific conductance data are continuously monitored at 15-minute intervals. Tide stage data are recorded at selected sites by Enviro Lab DL-150 or DL-800 data loggers and Fisher-Porter or Stevens punch papertape recorders using a float well system. Specific conductance is monitored by similar recorders modified to accommodate a salinity sensor. These instruments are battery operated and the data tapes are readily reduced through computerized operations.

Continuously recorded data are downloaded weekly from the data recorders onto floppy disks and brought to the office for analysis, summary, and permanent storage. Specific conductance and tidal stage data are stored as statistical analysis software (SAS) files after being subjected to analysis consisting of a series of programmed quality assurance and quality control (QA/QC) checks and visual inspection. Data passing QA/QC are included in the Annual Data Summary report and are exported to the Interagency Ecological Program's file server where they are available at Internet address http://www.iep.water.ca.gov.

Quality Assurance/Quality Control

Data collection and telemetry equipment are checked twice weekly during the compliance season and once weekly during the non-compliance season for proper functioning. Data about operational checks on the monitoring equipment and calibration materials are also collected during each visit for QA/QC over the continuous data.

Sample Representativeness

Monitoring stations were located throughout the Suisun Marsh in an effort to provide an accurate representation of specific conductance conditions in all portions of the Suisun Marsh. Placement of the stations appears to have provided representative data, with the exception of the northeastern portion of the Suisun Marsh, where data is lacking. Therefore, the extent to which this area has been affected by operation of the facilities cannot be addressed.

Data from select channel water salinity monitoring stations in the Suisun Marsh were used to represent applied water salinity at various monitored ownerships. Table 9 lists the channel water monitoring station used to represent applied water quality at each club. Figure 18 shows the locations of the clubs and monitoring stations. Most of the monitoring stations are located next to, or fairly close to, the intake for the associated club(s) and provide a salinity value representative of the applied water. However, Mallard, Goodyear, and Gum Tree are exceptions. Mallard Farms is located approximately two miles downstream of S-72, along the Roaring River Distribution System (RRDS). Station S-72 monitors the channel water entering the RRDS. Since there are no other sources of water entering the RRDS, the channel water salinity at the RRDS intake should be representative of the water further down the system at the Mallard Farms intake. A similar situation exists for Goodyear, which is located approximately one mile downstream of S-35. Although Morrow Island Club diverts water from Goodyear Slough, it drains into the Morrow Island Distribution System, which goes out into Grizzly Bay, and therefore does not impact Goodyear Slough salinity. No other sources of water enter Goodyear Slough between S-35 and the Goodyear intake, so channel water salinity at S-35 should be representative of salinity at Goodyear. The intake to Gum Tree is located on Montezuma Slough, approximately two miles upstream of S-54. The intake and drain for Island Club are also located along Montezuma Slough, directly across the slough from S-54. Therefore, channel water salinity at S-54 is likely affected by drainage from Island Club, as well as upstream drainage from Gum Tree. Consequently, there is the potential for more saline channel water conditions to exist at S-54 than exist upstream at the Gum Tree intake. However, this is not likely to be a significant concern, because clubs do not simultaneously drain and flood, except during circulation. When clubs circulate, the volume of water drained is not likely large enough to effect the channel water salinity. The volume of drainage water is small compared to channel water volume, and should not have a significant impact on channel water salinity. In addition, since most clubs follow a similar management schedule, it is not likely that Island Club would be draining while Gum Tree is flooding. Therefore, salinity values measured at the monitoring stations are considered to be representative of applied water salinity.

Data Limitations

Based on the method evaluation and QA/QC, the data are acceptable for the intended use.

Pond Stage Data

Pond water elevation data were collected on the monitored ownerships from October 1994 through September 1995. A discussion of the sample methodology, data quality evaluation, and sample results follows.

Table 9 Channel water monitoring stations and associated clubs

Monitoring Station	*Club(s)*
S-72 Roaring River at Montezuma Slough	Mallard
S-64 National Steel	Grizzly Island Wildlife Management Area
S-90 Roaring River at Sprig	Sprig
A-68 Grizzly King	Grizzly King
S-42 Volanti	Joice Island
S-54 Hunter Cut	Island Club, Gum Tree
S-21 Sunrise	Teal, Sunrise
S-33 Cygnus	Tule Belle
S-35 Morrow	Morrow Island, West Family, Goodyear

Method Evaluation

Pond stage recorders were used to monitor the water level on each of the monitored ownerships. Pond water levels were recorded by an ink pen on a drum style Stevens Type F recorder equipped with a float. Pond stage charts, retrieved monthly, provided graphical records of on-site water management practices, including flood duration and timing and depth of leach cycles.

Quality Assurance/Quality Control

Despite some mechanical and operator errors, these recorders accurately measured the water depth above pond bottom. To check the accuracy of the pond stage recorders, a graduated stake was also installed at each site, and during the monthly visits the actual water elevation at the stake was compared to the elevation measured by the recorder. The two measurements were usually in synch, and when they were not, recorder problems were looked for and corrected.

Sample Representativeness

Generally, the data collected were accurate only for the area where the recorder was located. Topography can vary greatly within a pond and the pond stage recorder was not representative of water levels across the pond. In some cases the recorder was placed in an area that was atypical of the pond, such as a low spot that recorded higher water depths than the rest of the pond; consequently, leaching events were not observable (PSR 85 at Grizzly Island, PSR 76 at Tule Belle).

In July 1992, SRCD requested that the pond stage wells be deepened to monitor the depth of leach cycles. The Stevens pond stage recorder is not designed to measure subsurface water levels, but DWR and SRCD agreed that the instrument might at least provide an indication of the depth and duration of leach cycles. Before water year 1993, the float wells were deepened to 1.5 feet below the surface. The resultant pond stage records do show a response to subsurface water levels, but these can not be taken as a precise measure of the water table elevation. One potential source of error is glazing of the walls of the float well that can occur during drilling of the well. Such glazing would affect ground water entry into the well.

Data Limitations

The pond stage recorder data were limited in that they were not adequate for determining when the clubs were circulating the water in the ponds. Data on circulation periods would have been important for determining when the ownerships were taking on water from the channels. Without this information it is difficult to accurately assess the relationships between channel, pond, and soil water salinity.

Pond Water Salinity

Pond water salinity data were collected at each soil tube site on the 14 monitored ownerships from August 1994 to September 1995 (see Table 8). A discussion of this monitoring follows.

Method Evaluation

Sites were visited monthly. When water was present in the pond, a one-pint grab sample of surface water was collected. Pond water pH was measured at the time of collection, and specific conductance measurements were performed by field technicians prior to sending samples to the DWR Bryte Chemical Laboratory. Most pond water specific conductance values in this report are those obtained from Bryte Laboratory.

Quality Assurance/Quality Control

Field Quality Control

Environmental Protection Agency (EPA) methods for sample collection, preservation, and handling of water were followed.

Laboratory Quality Control

Laboratory quality control procedures listed in EPA methods were followed. This included the analysis of the following: laboratory blanks, laboratory quality control samples, matrix spike samples, and duplicate samples. DWR's Bryte laboratory follows standard operating procedures to assess the accuracy and precision of all analytical procedures.

Sample Representativeness

Pond water salinity was evaluated from a single grab sample of pond water collected from the surface. Since the ponds were generally shallow, with a maximum depth of one foot, significant salinity stratification was not a concern. On clubs where the pond water was circulated, salinity was generally uniform throughout the pond, and grab samples were representative of pond salinity. Unfortunately, some clubs did not routinely circulate the pond water, and the grab samples may not provide a good estimation of salinity throughout the entire pond.

Data Limitations

No data quality limitations were found. However, because samples were collected as monthly grab samples, they represent only the salinity at the time of collection. Changes in salinity over the month are not available; consequently, short-term, immediate effects of management cannot be evaluated. Data can be used only to evaluate long-term changes and trends in salinity.

Drain Water Salinity

Drain water salinity data were collected for a limited period, with length of monitoring varying depending on the site (see Table 8). All monitoring occurred within the period of October 1981 through June 1994.

Method Evaluation

Specific conductance data were continuously monitored at 15-minute intervals. Data were recorded at selected sites by Enviro Lab DL-150 or DL-800 data loggers modified to accommodate a salinity sensor.

Quality Assurance/Quality Control

Field Quality Control

Channel and drain water were continuously monitored at 15-minute intervals. Instruments were checked weekly for accuracy and calibrated when necessary.

Laboratory Quality Control

Laboratory quality control procedures listed in EPA methods were followed. This included the analysis of the following: laboratory blanks, laboratory quality control samples, matrix spike samples, and duplicate samples. DWR's Bryte laboratory follows standard operating procedures to assess the accuracy and precision of all analytical procedures.

Sample Representativeness

Drain water specific conductance was measured at seven clubs in the Suisun Marsh. Drain water specific conductance for each club was determined from one specific conductance probe placed in a drainage ditch just inside of the drainage gate. In some cases, this method may not have provided representative samples due to variability of drain water specific conductance within the club. All of the clubs have at least three drains (most have more) at various locations along the club boundaries. The specific conductance of the drain water at one drain may not be the same as the drain water specific conductance at the other drains. For example, Tule Belle, Mallard, Grizzly King and Grizzly Island all had significantly variable pond water specific conductance values within the monitoring sites at each club. This would suggest that the specific conductance of the drain water from the various sites on each club would be different.

Other factors influencing the representativeness of the drain water specific conductance samples include evaporation and precipitation. Since the drain water specific conductance was continually monitored in the drainage ditch, significant precipitation could fill the ditch and result in an erroneous specific conductance value. Conversely, evaporation of standing water in the drainage ditch could register as erroneously high drainage water specific conductance values.

Data Limitations

No data quality limitations were found. However, due to limits on sample representativeness, drain water specific conductance values were only used as estimated values to evaluate the general trend of drain water specific conductance. Changes in drain water specific conductance during precipitation events were considered to be due to dilution of water within the drainage ditch. Drain water specific conductance values measured after final pond drawdown were not considered valid since they likely represent the specific conductance of stagnant water remaining in the drainage ditch.

Soil Water Salinity

Soil water salinity was measured monthly at the monitored ownerships during the period from August 1984 to September 1995 (see Table 8). During this period, the number and location of monitored sites varied based on site access or club management practices.

Method Evaluation

Soil water salinity was determined by use of soil water extraction tubes. The tubes were constructed using PVC pipe and porous ceramic cups. A vinyl tube extends from the bottom of the ceramic cup up through a rubber stopper inserted in the top of the PVC pipe. Soil water was extracted through the vinyl tube with a hand pump. After the water sample was collected, air was removed from the pipe to create a vacuum and allow water to seep back into the ceramic cup.

With this method, proper installation of the tubes results in effective collection of water. Proper installation includes techniques to avoid “glazing” of the walls of the hole the tube was placed in, which could impair the entry of water into the soil tube. No studies were done to assess possible “clogging” of the pores in the ceramic cup, so it is not known how (or if) the effectiveness of the tubes diminished over time. For each set of three tubes, the amount of water collected was sometimes substantially different for each tube, but the specific conductance of the three samples rarely had a range of more than 2 mS/cm.

One major limitation of this method of measuring soil water salinity is that the concentration of salts was measured but not the amount. This is further discussed in the “Data Limitations” section that follows.

Quality Assurance/Quality Control

Field Quality Control

EPA methods for sample collection, preservation, and handling of water were followed.

Laboratory Quality Control

Laboratory quality control procedures listed in EPA methods were followed. This included the analysis of the following: laboratory blanks, laboratory quality control samples, matrix spike samples, and duplicate samples. DWR’s Bryte laboratory follows standard operating procedures to assess the accuracy and precision of all analytical procedures.

Sample Representativeness

Sites were selected throughout the study area to record the horizontal variation in soil water salinity. Sites were chosen that varied in management practices and covered the five major soil types. The western, central, and eastern Suisun Marsh were all represented.

Soil, by nature, is heterogeneous. Therefore, it is difficult to thoroughly characterize the entire project area. Samples were collected in an attempt to represent both the vertical (top one foot) and horizontal soil water salinity within a club. Soil water salinity was monitored in the top one foot of soil, using soil water extractors installed, in triplicate, approximately 12 inches apart and six inches below the soil surface. The accuracy of determining the average soil water specific conductance in the top foot of soil using a single extractor at the six-inch level was evaluated after the first year of the study. Soil water specific conductance from the six-inch extractor was compared with the results from extractors placed three inches and nine inches deep on Reyes and Joice series soils at locations of both high and low surface water salinity. Results of the comparison indicated that specific conductance values between the three depths were negligible, and water extracted from the six-inch extractor adequately represented water quality within the top one foot of soil.

Data Limitations

Salt concentration is strongly affected by the amount of water in the soil; as moisture increases, salt concentration decreases. Because the moisture content of the soil was not measured, the actual amount of salt in the soil is not known. For example, two soil samples could have identical amounts of salt, but if one had twice the amount of water, it's salinity measurement would be substantially lower. Because of this limitation, comparison of soil water salinity between sites is problematic. In this document, annual soil water salinity averages are used in an effort to avoid possibly erroneous comparisons over the short term.

Vegetation Monitoring

Various vegetation surveys were conducted during the monitoring period. Vegetation was surveyed at each soil water monitoring site during August and/or September of each year to obtain vegetation occurrence data. At the late drawdown ownerships (extraction tubes at the six-inch depth only), alkali bulrush seeds were collected each fall to estimate production. Overall vegetative composition of the Suisun Marsh was determined by aerial photography and ground verification. A discussion of each type of vegetation monitoring follows.

Vegetation Occurrence Data Evaluation

Method Evaluation

Vegetation adjacent to each soil water monitoring site was surveyed using a variation of the traditional toe-point method as described and implemented by the DFG (Briden and Wernette 1993). Starting at the soil water extraction tubes, ten readings were taken along each of five randomly selected directional headings. These headings were selected for each site at the beginning of the monitoring program and were used every year to allow comparison of annual sampling efforts. Beginning ten feet from the soil water extraction tubes, one plant species encountered for every ten feet was recorded. The overall plant composition was then calculated for the site and recorded as percent occurrence.

The Monitoring Program methodology from the Suisun Marsh Plan of Protection required that, “the percent of cover contributed by each plant species present on the sample site will be determined.” The toe-point method does not measure percent cover, nor does it encounter every plant species present on the sample site.

The toe-point method is modified from the step-point method of sampling (Evans and Love 1957). The step-point method was originally developed for use in low herbaceous vegetation with fairly uniform structure, like rangelands. To randomly choose between plant species present at each intercept, the surveyor would hold his foot at a 30-degree angle to the ground and a pin would be placed in a notch in the boot toe and held perpendicular to the boot. The first plant intersected by the pin was noted as the plant species at that point. When used in the Suisun Marsh, the notch and pin were not utilized, and the surveyor made a subjective choice (haphazard selection) of which plant species present at the boot toe to record for each point. Selection of species was not necessarily the visual dominant at the sampling point. This survey method is inappropriate for vegetation with non-uniform canopy height like that present in the Suisun Marsh. A strong factor of surveyor bias was introduced by the elimination of the toe-notch and pin.

The toe-point method is one of several ways to estimate percent occurrence or frequency. Frequency is the percentage of total sampling points that contain at least one individual of a given species. Frequency is a more artificial statistic and has less biological significance than cover or density because frequency estimates will vary according to sampling design, plant distribution, and surveyor bias. Plant cover and density measurements give a clearer picture of how vegetation patterns change over time.

Data Limitations

The limited scope, incompleteness, and bias of the data collected make it impossible to determine vegetation trends or make accurate assessments of the effects of management and soil salinity on the vegetation. In addition, vegetation in the vicinity of the soil tubes was not necessarily representative of vegetation in the entire pond.

Because of limitations in the method, comments about recorded species do not imply percent cover, species abundance, or frequency of vegetation at a site. Also, other species may have been present.

Vegetation Production Data Evaluation

Method Evaluation

At the late drawdown ownerships (extraction tubes at the six-inch depth only), alkali bulrush seeds were collected each fall to estimate production. Seeds were collected by clipping seed heads from all alkali bulrush plants growing within a one square meter area near the soil water extraction tubes. The one square meter area was a non-random area selected for a high density of alkali bulrush stems and large quantity of seed heads. Seed heads were air dried, and the seeds were separated out and weighed to the nearest one-tenth of a gram. Results were converted to pounds per acre of seed production.

At the early drawdown ownerships (soil extraction tubes at 6, 18, and 30 inch depths), fat hen samples were collected by clipping all fat hen above ground level within a one-square meter area near each soil water extraction site. The non-random, one-square meter area was chosen for a high density of fat hen. Samples were air dried and weighed to the nearest one-tenth gram without attempting to separate fat hen seeds from other vegetative parts. Results were then converted to pounds per acre of total fat hen biomass.

The Monitoring Program methodology from the Suisun Marsh Plan of Protection required that, “seed yield will be measured by clipping the seed heads from all plants contained within a square meter plot…and the results reported in pounds per acre.”

Although the method used satisfied the Suisun Marsh Monitoring Agreement, it is impossible to evaluate whether the clubs in the Suisun Marsh achieved the seed germination and production goals upon which the D-1485 standards were based. In addition, the method to measure alkali bulrush and fat hen biomass production was inadequate and can be misinterpreted.

Data Limitations

The use of a single, non-random sample does not provide an accurate estimate of seed production in the area around the soil tubes. Because the seeds were collected from an area chosen for a high density of seed heads or biomass, the result overestimates the actual seed production of the alkali bulrush or fat hen in the area. The conversion of grams/m^2 to pounds/acre also gives a misleading estimate of the seed or biomass production since the area of concern (that within 35 meters of the soil tubes) is much less than an acre. In addition, the area is almost always a mix of plant species, not solely alkali bulrush or fat hen. Estimating plant productivity for a club which may be several hundred acres in size from a one square meter sample is not statistically valid.

A more accurate method of measuring production would require estimating percent cover of the species of interest and taking random samples of seed heads or biomass within several different stands of that species.

Triennial Vegetation Survey Data Evaluation

Method Evaluation

The Monitoring Program methodology from the Plan of Protection required that, “the overall vegetative composition of the Suisun Marsh shall be determined every third year using color aerial photography in conjunction with ground verification. The results…will be compared to the results from past flights and will be reported in acres and percent of total vegetation for each major plant species.” These surveys were completed in 1981, 1988, 1991 and 1994.

Aerial photographs of the Suisun Marsh were taken during a low tide in June, and 9 x 9-inch color prints were provided at a scale of 1 inch to 800 feet. Prior to ground truthing, each aerial photograph was examined using a magnifying lamp, and areas of similar color, pattern, and texture were outlined. Within each area, the number and length of transects necessary for ground truthing was determined by the size and homogeneity of the area, and ranged from 1 to 30.

Ground truthing occurred during the summer months. On each transect, the type of vegetation encountered at five meter intervals was determined using the toe-point method described previously in the “Vegetation Occurrence” section. For each transect, the vegetation composition was entered as a percentage for each species encountered. These percentages were then applied to areas of similar appearance in the aerial photos. The acreage of each habitat type was determined using a planimeter. Acreage of the habitat types was then multiplied by the percent occurrence of the species within the habitat to determine the acreage for individual species on each photo. Acreage values for each species were summed from all of the photos.

In addition to monitoring vegetation change across the Suisun Marsh, the Triennial Survey was supposed to monitor the acreage of preferred salt marsh harvest mouse habitat (for details see the “Salt Marsh Harvest Mouse” section that follows). To assist in this, the Suisun Marsh was divided into five zones to decrease the potential for significant local decreases in habitat being masked by increases in other areas of the Suisun Marsh. These zones were established before the 1981 survey, and were used to analyze vegetation changes in each subsequent survey.

For the 1994 survey, ground truthing was done before the aerial photos were available to field personnel. In ponds selected for sampling, a visual estimate was made of the number of habitat types within the pond. Transects were run through each habitat type using the toe-point method. Transect locations were marked on topographic maps and later transferred to the aerial photos. Data from the transects were used to first delineate habitat types on the photos and then to determine percent occurrence of individual species within the habitat type.

As discussed in the “Suisun Marsh Monitoring Program” section, a new vegetation survey methodology is currently being developed by DFG’s Habitat Conservation Division. The next survey will be conducted in summer 1999.

Data Limitations

The requirement that results "be reported in acres and percent of total vegetation for each major plant species," is not the best method to describe the vegetation in the Suisun Marsh. While it is possible to determine precise acreages of species of concern, methods used in this program do not result in information at this level of detail. Determination of individual species composition marshwide would require an extremely intensive sampling effort with rigorous replication to report data at the species level with any degree of certainty. On the ground, marsh habitats are mixed assemblages of several species rather than monotypic stands. To lump percentages of species within each habitat into single species categories loses the character of the actual habitat.

The limitations and bias of the toe-point method are discussed in detail in the preceding "Vegetation Occurrence" section. This method was not designed for use in multi-layered habitats, and as employed, introduced a significant level of surveyor bias, and did not include necessary replication to determine sample variance and certainty of ground-truthing. It is not an appropriate method for detecting all the species present in the habitat, or for determining the cover or density of species within the habitat. Thus, the bias and incompleteness of the data, coupled with grouping of the data into single species categories, did not result in an accurate representation of the vegetative composition of the Suisun Marsh.

The five zones established in the Suisun Marsh have not been used for their original purpose of assessing changes in preferred salt marsh harvest mouse habitat. In addition, the triennial survey was to be compared with annual vegetation monitoring transect data from the 1,000 acres of preferred set-aside areas of salt marsh harvest mouse habitat across the Suisun Marsh. The aerial photo interpretation and annual vegetation monitoring were not implemented.

Salt Marsh Harvest Mouse Surveys

The salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) is endemic to Suisun Marsh and the marshes of San Francisco Bay (USFWS 1984). The mouse was listed as an endangered species by the USFWS in 1970 and the California Fish and Game Commission in 1971.

In 1981, the USFWS issued a Biological Opinion for the Suisun Marsh Plan of Protection. In the Biological Opinion, the USFWS expressed concern that the implementation of the Preservation Agreement and more intensive management practices on both State and private wetlands could result in the reduction of preferred salt marsh harvest mouse habitat. To compensate for this potential loss, the USFWS required the DWR and the DFG to provide 1,000 acres of marshland as preferred salt marsh harvest mouse habitat, toward a long-term goal of retaining "2,500 acres of preferred salt marsh harvest mouse habitat adequately distributed throughout the marsh" (DWR 1984).

The DFG set aside seven areas totaling more than 1,000 acres of State land in Suisun Marsh to fulfill this requirement. In addition, 100 acres of salt marsh harvest mouse habitat on Island Slough was acquired as mitigation for SMPA activities. Figure 6 shows the seven set-aside areas, plus Island Slough. The DFG prepared a management plan for the set-aside areas (Wernette 1987) that included (1) water and habitat management of areas set aside as salt marsh harvest mouse habitat, (2) future acquisitions of salt marsh harvest mouse habitat, (3) monitoring to establish baseline conditions of the seven set-aside areas, (4) ongoing monitoring of the vegetation and mouse populations of the seven set-aside areas including annual surveys along permanent vegetation transects and mouse surveys every three years in conjunction with a triennial vegetation survey and (5) project review.

The Monitoring Program methodology from the Suisun Marsh Plan of Protection required that the marsh-wide aerial photo survey for the Triennial Vegetation Survey also “be used to monitor the extent of preferred salt marsh harvest mouse habitat.” The Biological Opinion for the Suisun Marsh Plan of Protection states: “Current pickleweed areas will be mapped using the planned 1981 [triennial vegetation survey] flight. Ground truthing will then be used to determine the approximate acreage of preferred mouse habitat that meets the density, height, and condition requirements…A change in preferred mouse habitat will be significant when the acreage decreases by one-third in any [one of five] zone (based on data from ground verification of the 1981 flight).”

Method Evaluation

Salt marsh harvest mice were trapped with Sherman live traps baited with a mixture of bird seed and ground walnuts. In addition to bait, a single paper towel was placed in each trap to provide bedding if an animal was captured. Traps were set in the late afternoon, and checked early the next morning. Trapping was conducted only in areas identified as suitable habitat. All captured animals were identified and released at the site of capture. Criteria developed by Shellhammer (1984) were used to differentiate the salt marsh harvest mouse from the western harvest mouse (*Reithrodontomys megalotis*).

Data Limitations

The techniques used during salt marsh harvest mouse trapping are standard practice for small mammal surveys.

Although the triennial vegetation surveys measured the acreage and percentages of pickleweed (see previous critique), there were no surveys for preferred salt marsh harvest mouse habitat. It has not, therefore, been possible to assess changes in the acreage of preferred habitat. In addition, because the vegetation was categorized by species rather than habitat type, the actual acreage of pickleweed-dominated habitats cannot be determined by the survey results.

Aquatic Resources Monitoring

Neomysis

Method Evaluation

Since 1972, the DFG has conducted field sampling for zooplankton and *N. mercedis* in Suisun Marsh. In 1976, DFG crews began taking chlorophyll *a* samples as well. Historically, three sites (S-32, S-33, S-34) were sampled in Montezuma Slough and one in Suisun Slough (S-42) (see Figure 19). *Neomysis* sampling station S-33 was discontinued in 1977, and S-34 was discontinued in 1984. (Please note: these stations should not be confused with the DWR Suisun Bay and Marsh Compliance Stations which have similar names.) Since 1984, only S-32 and S-42 have been sampled. The site on Montezuma Slough is about 15 miles downstream of the SMSCG, at the western end of the slough. Until 1996, N. mercedis and phytoplankton sampling occurred twice monthly from March through October. Normally there was no sampling from November through March due to naturally low winter abundance of *N. mercedis*. However, in water years 1996 and 1997, *N. mercedis* and chlorophyll *a* sampling were conducted monthly throughout the year.

At each site, one *N. mercedis* sample, two zooplankton samples, and one chlorophyll *a* sample are taken. Since 1994, numbers of *Acanthomysis bowmani*, a mysid species that has recently invaded from Asia, have also been enumerated. Surface temperature, water clarity (Secchi depth), and specific conductance are also measured. *Neomysis mercedis*, *A. bowmani* and larger zooplankton are sampled using a bottom-to-surface oblique tow through the water column with nets attached to a tow frame. Tows last ten minutes. The *Neomysis mercedis* net used since 1974 has a mesh size of 0.505 mm, a mouth diameter of 30 cm, and a length of 1.48 m. The zooplankton net, which is mounted above the *N. mercedis* net, is made of No. 10 nylon mesh, has a mouth diameter of 10 cm, and a length of 73 cm. To sample for microzooplankton, a hose is raised from the bottom to the surface of the water column. At the same time, water is pumped through the hose into a carboy. Subsamples are taken from the water in the carboy. Water for chlorophyll a samples is taken from a depth of one meter.

Data Limitations

In the analysis we compare abundance trends before and after SMSCG installation at two stations in the Suisun Marsh. As explained in the introduction, we can not directly address the question of whether SMSCG operations are affecting abundance of phytoplankton and zooplankton since the “control” or “background” condition (in other words, no SMSCG operation) no longer exists. The phytoplankton community has been greatly affected by the wide spread distribution of *Potamocorbula amurensis* since 1987 (Monroe and Kelly 1992). *Neomysis* have likely declined as a result of food limitation (in other words, lack of phytoplankton) and from competition with introduced mysids (Orsi and Mecum 1994). These confounding factors make it difficult to separate out effects of SMSCG operation.

General Fish Abundance

Method Evaluation

Since 1980, DWR has contracted with the University of California, Davis (UC Davis) to monitor fish populations in Suisun Marsh. Monthly samples are taken year-round with a four-seam otter trawl with a 1 m by 2.5 m opening, a length of 5.3 m, and mesh sizes tapering from 35-mm stretch in the body of the trawl to 6-mm stretch in the cod end. Biologists tow the trawl at 4 km/hr for 5 minutes in the small sloughs (seven to ten meters wide and one to two meters deep) and for ten minutes in large sloughs (100 to 150 m wide and two to four meters deep). Seining is done with a beach seine 10 m long with a mesh size of 6 mm.

Until 1994, UC Davis researchers trawled at 17 stations throughout Suisun Marsh and seined in Suisun Slough (Figure 20). Fifteen of the stations are in western Suisun Marsh and two are in eastern Suisun Marsh, both downstream of the SMSCG. To provide more representative sampling of Suisun Marsh species, in March 1994 researchers added two otter trawling sites in Nurse Slough and two otter trawling sites and one seining site in Denverton Slough.

At all sites, captured fish are counted, up to 30 individuals of each species are measured to the nearest millimeter standard length, and all fish are returned to the slough. Fish captured in the net range from 12 to 600 mm standard length. Researchers also record actual numbers of *Crangon franciscorum* and *Palaemon macrodactylus* and estimate the abundance of *Neomysis mercedis*. Channel water salinity, temperature, and clarity are recorded at each site. Tidal conditions are determined using the Tidelog.

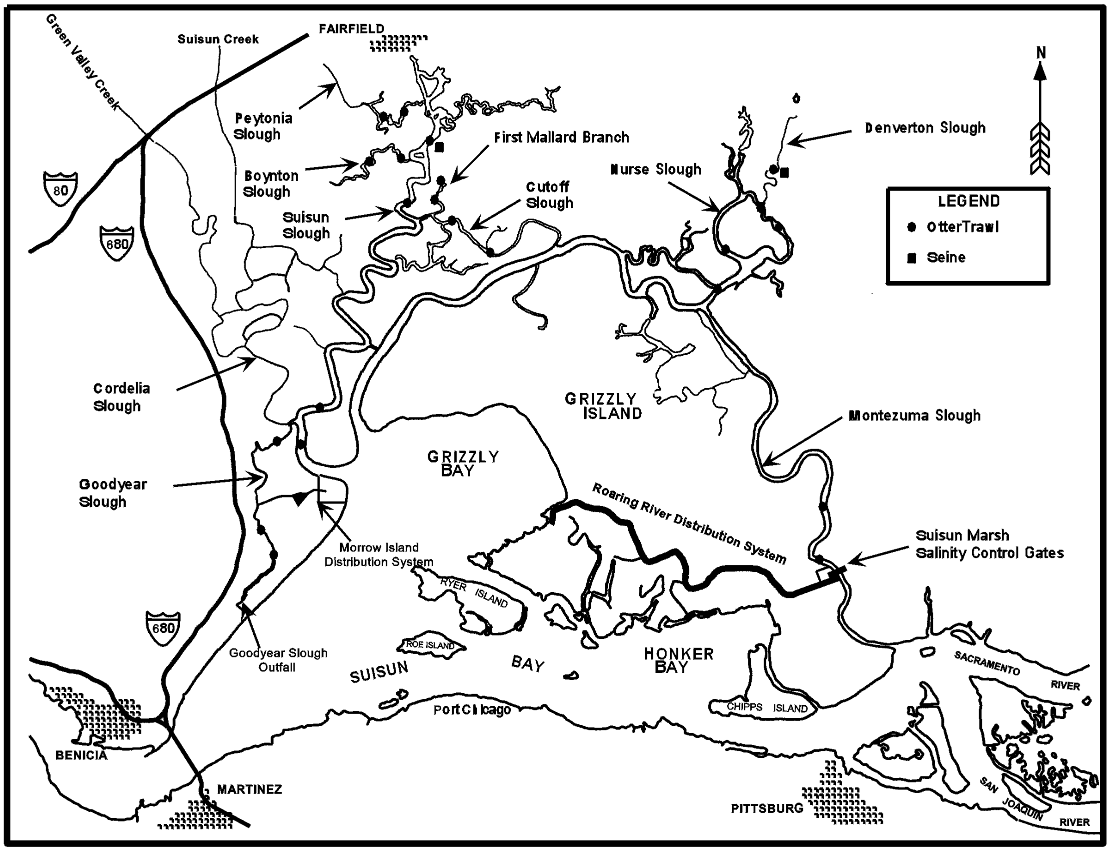

Figure 20 Location of UC Davis fish monitoring in Suisun Marsh

Data Limitations

The data can not be used to evaluate direct effects of SMSCG operation due to the reason described in the introduction. The relationship between fish abundance and SMSCG operations is not well understood. Comparisons of trends in fish abundance before and after the installation of the SMSCG can be made. An analysis of indirect SMSCG effects is performed to examine if changes in salinity brought about by operation of the SMSCG are affecting the abundance of native Suisun Marsh fish.

Striped Bass Eggs and Larvae

Method Evaluation

Striped bass spawning is triggered by water temperature, so egg and larval survey dates vary from year to year between February through July. In years before 1991, the survey was initiated early enough to collect eggs and larvae from early striped bass spawning. In 1991, sampling was done weekly from February through mid-July to encompass the delta smelt spawning period. Beginning in 1992 at Suisun Marsh and Suisun Bay sites, sampling was conducted every four days. In 1995, sampling frequency was decreased to every eight days at these sites. To collect the samples, ten-minute oblique tows were made at each station. The net used to collect the samples is 3.18 meters long and is made of 500-micron mesh. Until 1995, sampling occurred throughout Suisun Marsh, Suisun Bay, the Sacramento-San Joaquin Delta and the Sacramento River. In 1995, several sampling stations were eliminated. Figure 21 shows past and present sampling stations through 1995. Sampling in Suisun Marsh was not conducted after 1995.

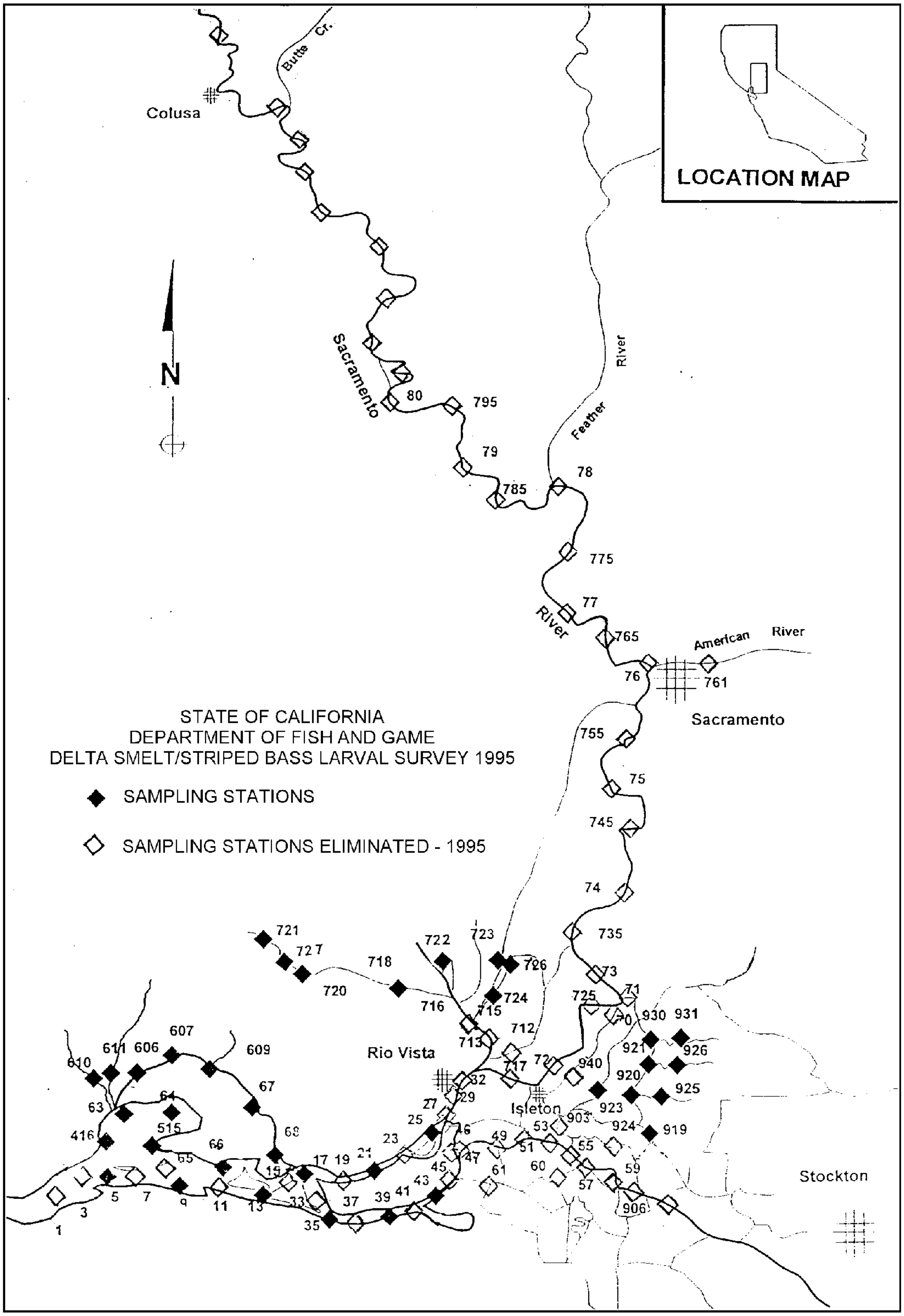

Figure 21 Sampling stations for the delta smelt and striped bass larva survey

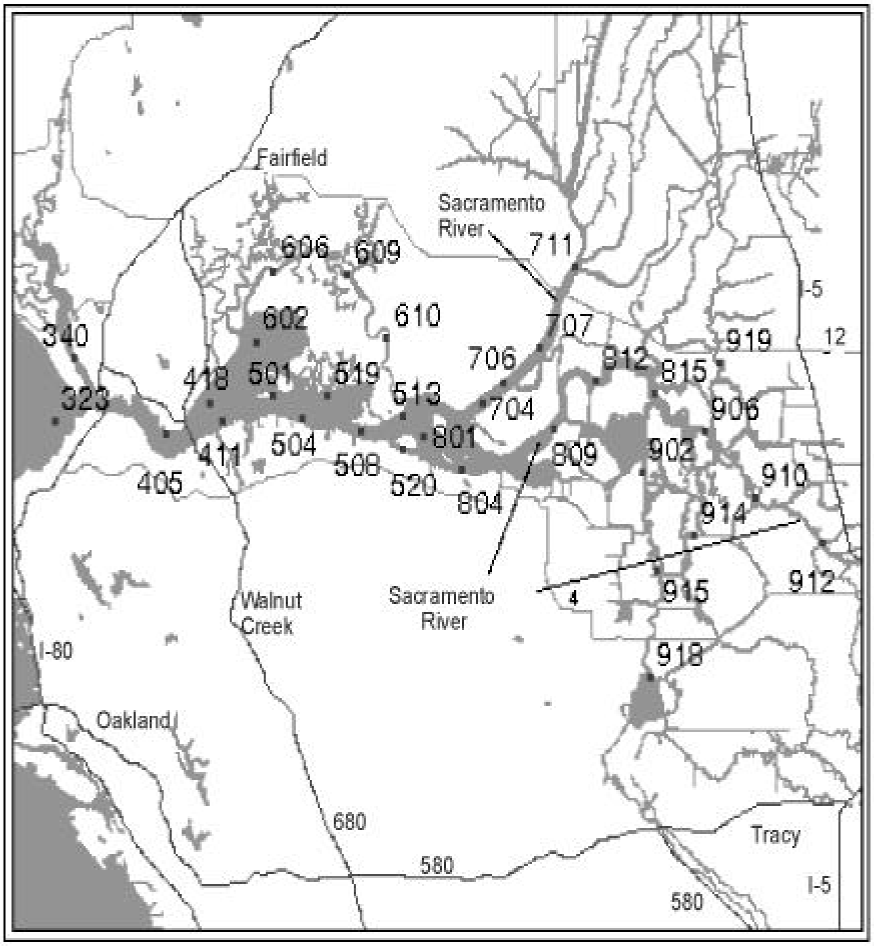

Figure 22 Striped bass tow-net survey stations (from Foss and Miller 1996)

Data Limitations

The data can not be used to evaluate direct effects of SMSCG operation due to the limitations discussed in the introduction. The relationship between striped bass larval abundance and SMSCG operations is not well understood. Comparisons of trends in abundance before and after the installation of the SMSCG can be made.

Juvenile Striped Bass

Method Evaluation

Surveys are conducted every two weeks in Suisun Bay and the Sacramento-San Joaquin Delta until the index size is reached or exceeded. Samples are taken during an oblique 10-minute tow at a standardized boat speed. Due to variations in environmental conditions, survey dates vary from year to year within the months of June, July, and August. Spring and summer conditions affect spawning time and larval growth and, hence, the time at which young become vulnerable to the sampling gear. Sampling begins when the young striped bass reach about 17.8 mm and continues until mean catch length is greater than 38.1 mm. Sampling stations are shown on Figure 22.

Data Limitations

The data can not be used to evaluate direct effects of SMSCG operation. Comparisons of trends in abundance before and after the installation of the SMSCG can be made. We compare the trends in the Sacramento-San Joaquin Delta and Montezuma Slough average 38.1 mm striped bass abundance indices since 1959.

Sampling to Estimate Chinook Salmon Losses and Use of Montezuma Slough as a Migration Corridor

Method Evaluation

In 1987, 1992, and 1993, USFWS biologists sampled in Montezuma Slough; in 1994, DFG biologists sampled Montezuma Slough. Sampling techniques in all years were similar to the standard midwater trawl methods employed at Chipps Island. The net used at Chipps Island is 6.0 m x 3.4 m with a 20.4 m^2 mouth. The net used in the Montezuma Slough is 2.4 m x 2.3 m with a 5.5 m^2 mouth. The gear used at Chipps Island sampled a cross sectional area of approximately 0.76% of the total width, while a cross sectional area of 5% of the total width was sampled in Montezuma Slough (NMFS 1994).

In 1987 and 1992, each survey consisted of four 20-minute tows per day at the sites shown in Figure 23. In 1987, USFWS researchers trawled downstream of the future SMSCG location. In 1992, they trawled downstream of the SMSCG, which were operating full bore. In 1993, each survey consisted of five tows above and five tows below the SMSCG with ten tows at Chipps Island. The trawls lasted 20 minutes. The SMSCG did not operate during this period, but the flashboards were in place. Two of the gates were operating full bore during the 1994 sampling by DFG staff. The third gate was closed for repairs. DFG researchers generally made six 20-minute trawls above and below the gates. On each day of sampling in 1994, the USFWS biologists made ten 20-minute trawls at Chipps Island. Staff constraints prevented researchers from conducting the juvenile chinook salmon sampling in Montezuma Slough in 1995.

Water year type and stream flow patterns influence the emigration patterns of chinook salmon (NMFS 1994). DWR staff compared model generated flows in Montezuma Slough to understand how operation of the SMSCG affected flow pattern in Montezuma Slough during the 1987 and 1992 through 1994 juvenile salmon sampling. The DWR Suisun Marsh Planning Section ran the 1987, and 1992 through 1994 water year hydrologies with the Delta Simulation Model (Suisun Marsh version). To provide the best estimate of actual conditions, all simulations were run using 15-minute data from historic tidal conditions and historic gate operations. All flows discussed are model generated data.

Data Limitations

Pre- and post-project results were inconclusive because of several factors:

1. Fish use of Montezuma Slough varied by year.

2. The sampling was not adequate to show the difference in fish use before the SMSCG were installed (1987) and after the SMSCG were in place (1993 and 1994).

3. SMSCG operations varied between years. In 1992 and 1994, the gates were operated during the sampling. They were not operated in 1993.

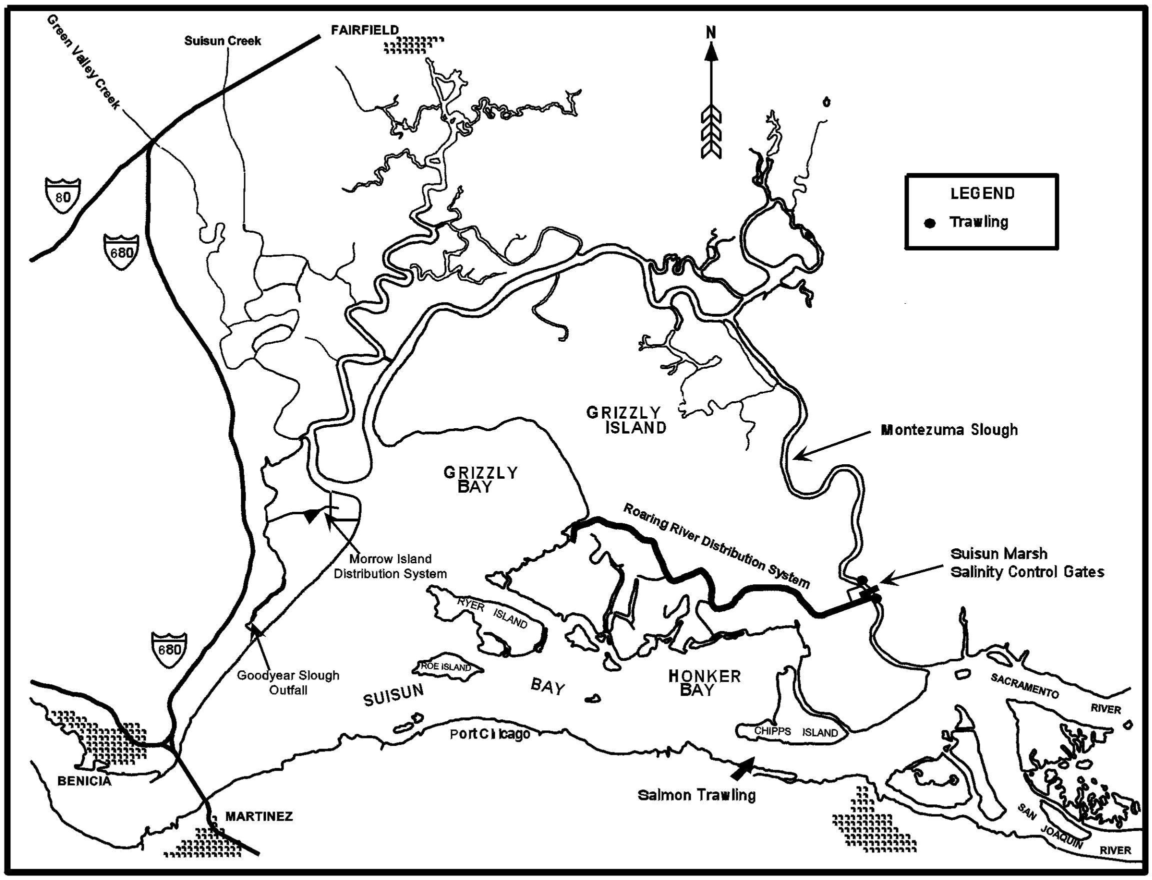

Figure 23 Location of juvenile salmon trawling in Montezuma Slough and at Chipps Island

4. Sampling locations changed. To estimate the use of Montezuma Slough by juvenile chinook salmon, trawling was done upstream of the SMSCG in 1993-1994 but downstream in 1992.

5. Because of the differences in gate operation between years, flow into Montezuma Slough may have varied also. In general, usefulness of the data has been limited by variations in gear efficiency and small sample sizes.

Sampling to Determine if Predator Abundance Increased Near the Salinity Control Gates

Method Evaluation

From 1987 to 1992, adult fish were collected during daylight hours at about two week intervals during May and June. DFG fished variable mesh gill-nets (a 200 ft long by 12 ft deep monofilament stationary net and a nylon drift net, both with mesh sizes of 2.4- to 4-inch stretch mesh) upstream (east) and downstream (west) of the structure (Figure 24). They used stationary nets to fish near the banks of the slough. DFG identified fish to the species level and took fork length measurements (mm). Stomach contents of potential predators (striped bass and Sacramento pikeminnow) were examined for remains of salmon, striped bass, and other prey.

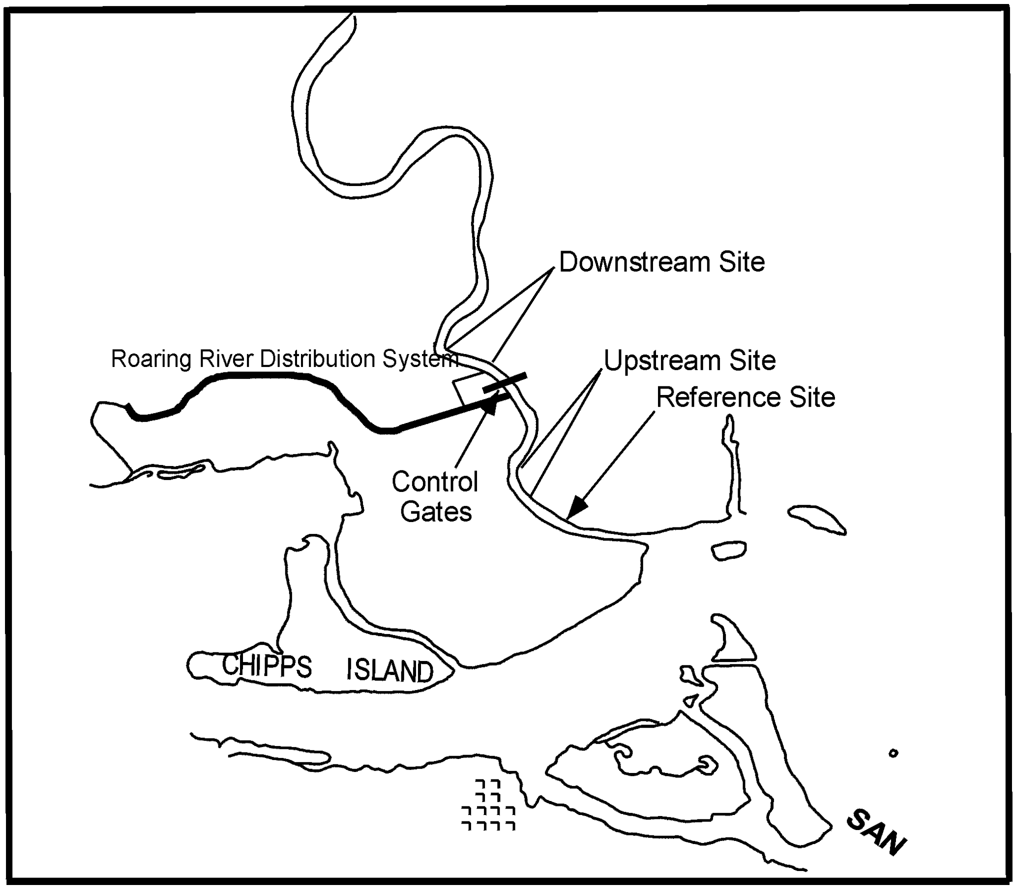

Figure 24 Locations of predator gill-netting near the Suisun Marsh Salinity Control Gates

Methods used in 1993 were the same as those in previous years with the addition of a third site, the reference site. The reference site was two miles upstream of the SMSCG. The other two sites were within one-quarter mile upstream and downstream of the SMSCG. The researchers monitored the three stations for 24 hours a day for 2 two-day periods. At each site, a stationary gill-net was fished for one hour and a drift-net was fished for 20 minutes. Nets were checked at the end of the sampling periods. DFG identified the fish to the species level and measured the fork length in millimeters, then the nets were moved to the next site downstream. The stomachs of striped bass and Sacramento pikeminnow ≥180 mm long were pumped. Researchers examined stomach contents for juvenile salmon and other prey species. The SMSCG were in the open position during the entire 1993 sampling period.

DFG also electrofished for prey fish species at all three sites in 1993. They covered 1,000 ft of shoreline on each side of the sites. The researchers sampled from 0.53 to 1.08 hours at each site and counted and identified fish to species. Sampling was discontinued after the completion of the 1993 sampling.

Data Limitations

It was difficult to detect the presence of juvenile salmon in the stomachs of striped bass and Sacramento pikeminnow. Fish are known to regurgitate stomach contents when they are captured in gill nets. Digestion rates vary with water temperature, body sizes of predators and prey, meal size and meal frequency (Adams and others 1990). The variation in digestion rates makes it difficult to determine the importance of various prey in a predator's diet.

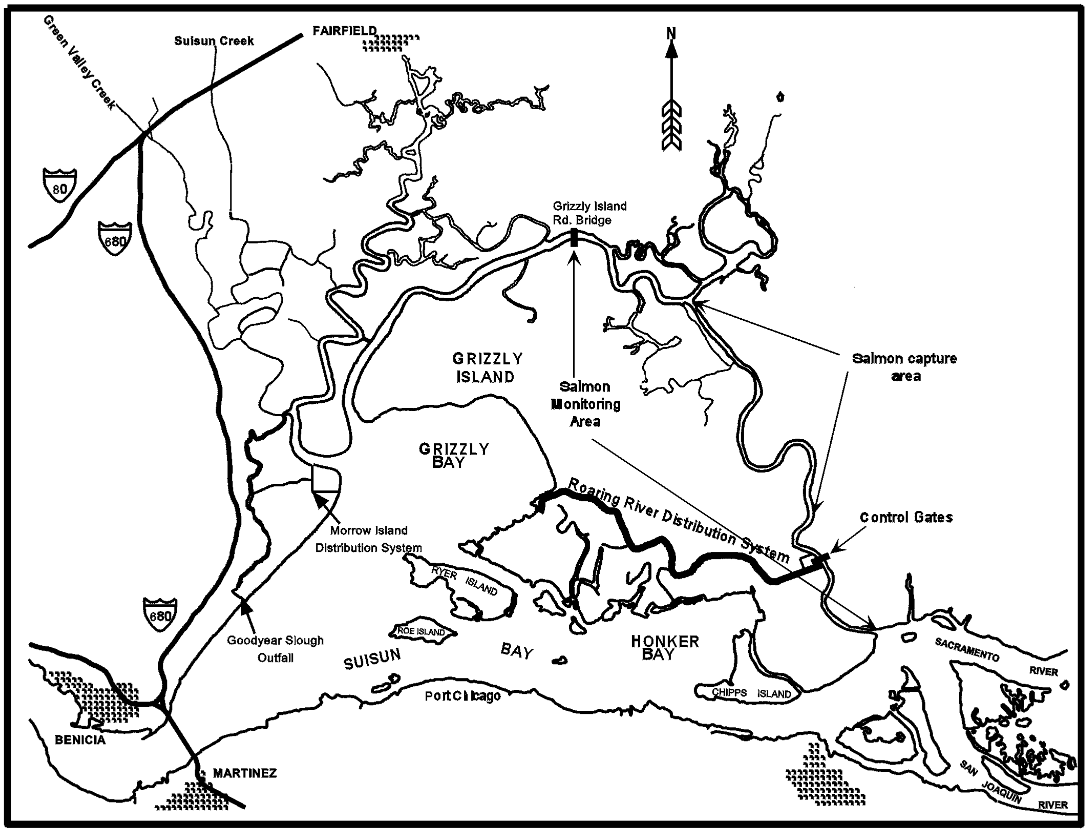

Figure 25 Study map of adult salmon capture and monitoring areas in Montezuma Slough from August to October 1993

Sampling to Determine if Gate Operation Delays the Migration of Adult Salmon

Method Evaluation

To determine the effects of SMSCG operation on migrating adults, a sonic tracking study was conducted from 24 August through 4 October 1993 and 26 September through 14 November 1994. Researchers captured, tagged, and monitored adult fall-run chinook salmon during three phases of SMSCG operation:

- While the gates were open and the flashboards were not in place.
- While the gates were open and the flashboards were in place.
- While the gates were operating and the flashboards were in place.

The purpose of the studies was to measure adult salmon passage success and duration under each operational configuration of the SMSCG.

Salmon were captured by using a nylon drift gill-net measuring 200 ft by 12 ft, with a 5.5- to 7-inch stretch mesh. DFG researchers fished the net from Little Honker Bay to one-half mile north of the SMSCG (Figure 25). They removed the salmon from the net as soon as possible. Each salmon was measured, a fin was clipped, and a sonic tag was inserted into the stomach.

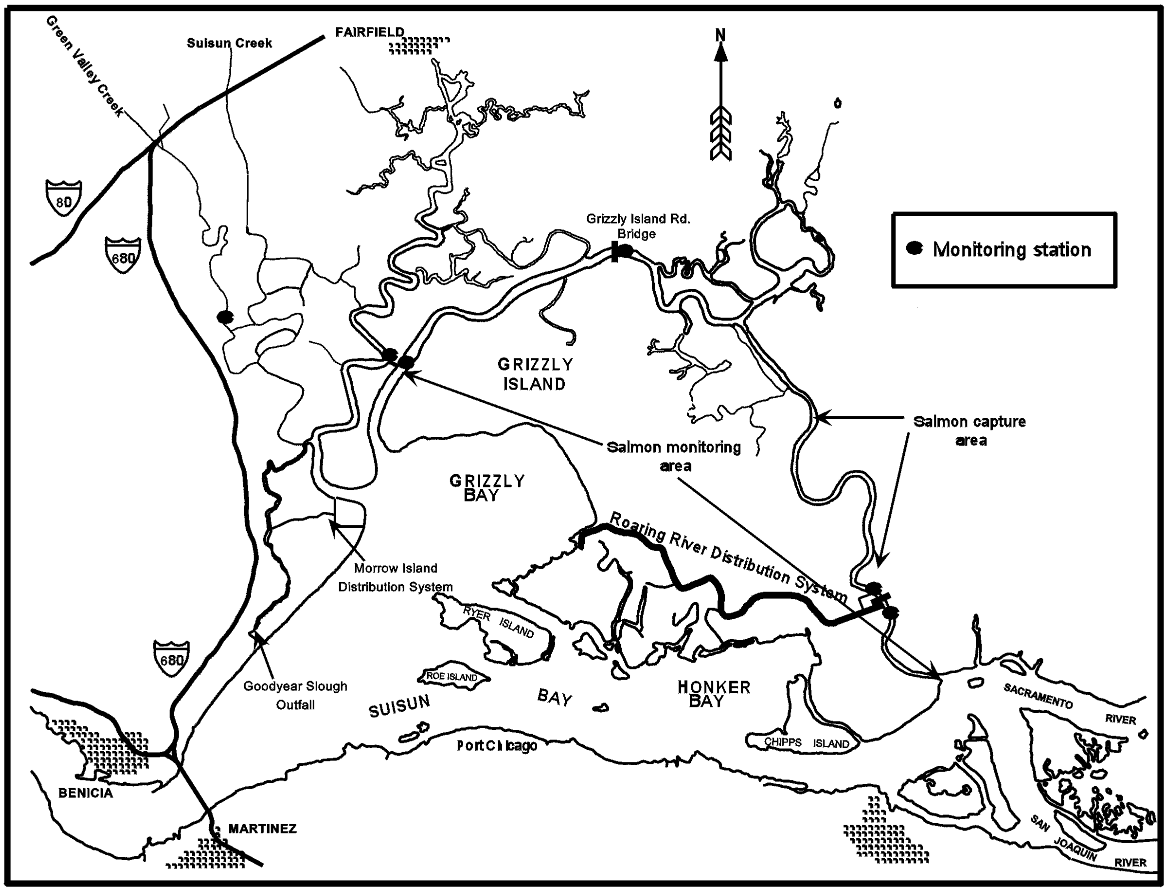

Figure 26 Adult salmon capture and monitoring areas in Suisun Marsh in 1994

In 1993, sonic tag monitoring was conducted with a boat and two stationary monitoring stations, one on the downstream side (Station 2) and one on the upstream side (Station 1) of the SMSCG. DFG biologists conducted boat monitoring from the upstream mouth of Montezuma Slough, near Collinsville, downstream to Beldons Landing in 1993 (see Figure 25). Because only two stationary monitoring stations were present during the 1993 study and because boat monitoring was only conducted downstream to Beldons Landing, the downstream movement of 17 tagged fish that did not pass through the SMSCG during the 1993 study could only be hypothesized. To provide data on fish that displayed this behavior pattern, the researchers added four stationary monitoring sites (Stations 3 through 6) to the study area in 1994 (Figure 26). They also extended the boat monitoring area from the upstream mouth of Montezuma Slough downstream to Hunter Cut.

In both years, DFG scientists monitored by boat for at least five days for each phase. In 1993, initial tracking was continuous for the first 24 hours of each phase, and subsequent tracking was done for six to eight hours every day. In 1994, they performed initial tracking continuously for the first 48 hours of each phase, and subsequent tracking was done for six to eight hours every Monday, Wednesday, and Friday.

During the 1993 study, concerns were raised that water temperatures greater than 20 ºC could affect the behavior of tagged salmon and increase the mortality due to handling stress. Consequently, the researchers agreed that the 1994 study would not begin until maximum daily water temperatures measured less than 20 ºC for a two-week period. This did not occur until late September 1994.

In each water year, the SMSCG are normally operated from October through May. Operation of the SMSCG in October helps to lower the channel water salinities in Suisun Marsh and provide low salinity water for the fall flood-up period for the waterfowl clubs. However, completion of the adult salmon migration study required that the SMSCG not be operated during two phases of the study. Delaying the start of the study until late September, when water temperatures were lower, resulted in the study period overlapping with the normal October operation of the SMSCG. To meet the needs of the adult salmon migration study and the waterfowl clubs, DWR began SMSCG operation on 3 September 1994. Operation of the SMSCG was suspended from 8 October to 14 November to complete the second and third phases of the study.

Initiating SMSCG operation in September required a change in the order of the adult salmon migration study phases. In 1994, the first phase was conducted from 26 September to 8 October with the flashboards in place, gates tidally operated, and the boat lock operated. The second phase, with the flashboards in place, gates not operated, and the boat lock closed, was conducted from 11 to 24 October. The third phase was conducted from 31 October to 14 November, with the flash boards out, the gates and boat lock not operated. In 1993, the first and third phases were reversed. The change in the order of study phases also minimized the chance of different runs of salmon affecting passage results for each operational phase.

Data Limitations

The significance of the delay for migrating salmon on a population level is unknown.

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